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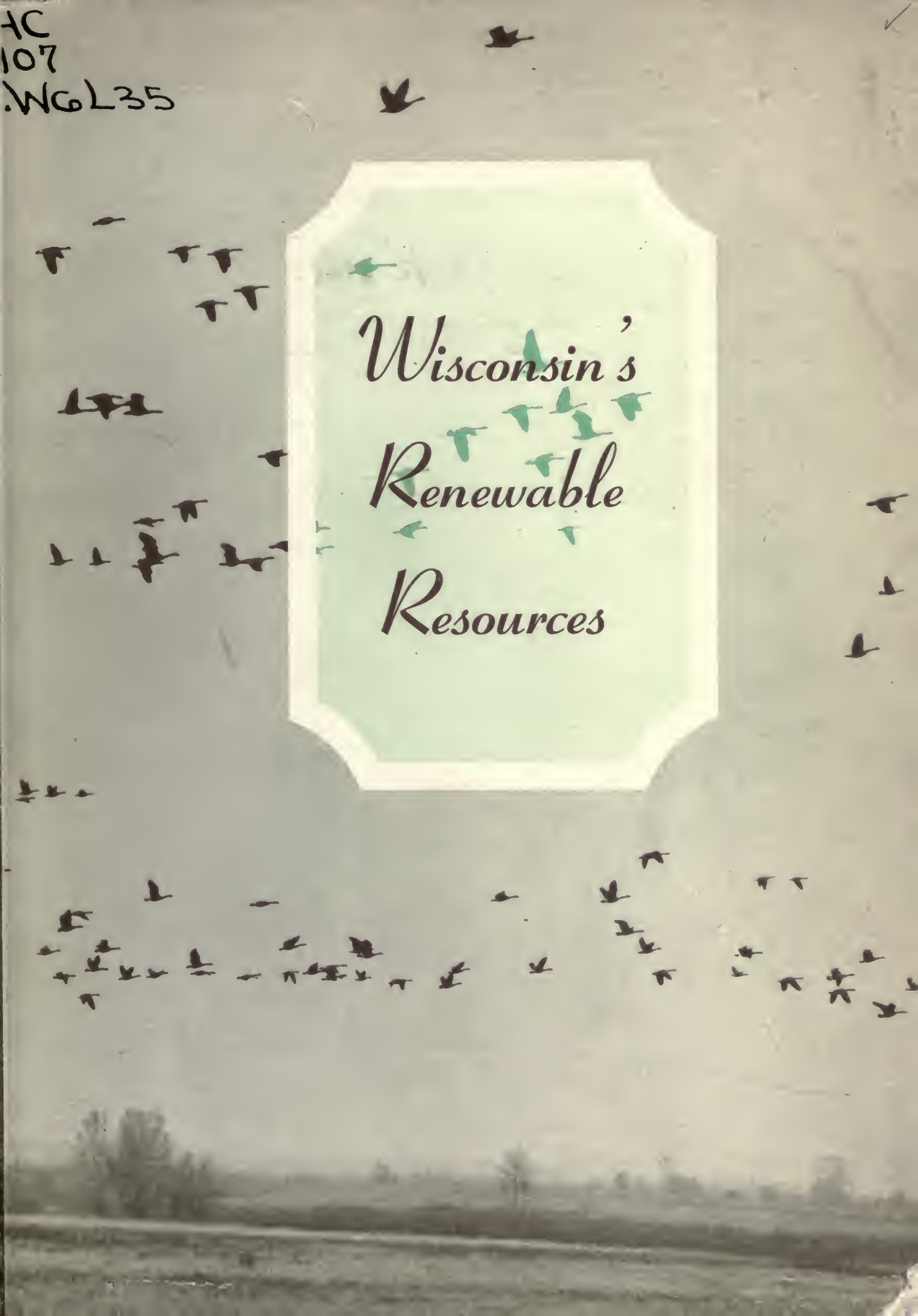
Wisconsin's Renewable Resources



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Wisconsin's Renewable Resources

by JAMES A. LARSEN, *Science Editor*
UNIVERSITY OF WISCONSIN NEWS SERVICE

PUBLISHED BY THE UNIVERSITY OF WISCONSIN WITH FUNDS
SUPPLIED BY THE WISCONSIN ALUMNI RESEARCH FOUNDATION

WITHDRAWN

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A REPORT ON RESEARCH AT THE UNIVERSITY OF WISCONSIN

Into the Renewable Resources of Field, Forest, Lake and Stream

"In this university during the past 100 years there has probably developed more ecological understanding than in any other in the Western Hemisphere. Through the investigations done here, through Wisconsin publications, and through the impact of former Wisconsin students—now being felt more powerfully than ever before—the minds of men have been influenced not only here, but in Great Britain, Europe, and Latin America.

—WILLIAM VOGT

"The invincible Wisconsin has been fighting for ages for a free passage to the Mississippi, and only this crooked and narrow slit has been granted or gained. At present all is peace, but the river, though calm, does not appear contented. Only a few foam-bells are seen, but they float with an air of tardy settled sullenness past the black yawning fissures and beetling, threatening rockbrows above."

—John Muir

This book takes as its point of departure the gift to the Wisconsin Alumni Research Foundation in 1954 of the property surrounding the Dells of the Wisconsin River, a scenic portion of Wisconsin that typifies for many visitors the beauties of the Badger State. The property was transferred to the Foundation by the heirs of Mr. and Mrs. George H. Crandall. For many years, the Crandalls dedicated themselves to protecting the natural beauty of the Dells, and that heritage was maintained by Mr. and Mrs. Howard Musson and Dr. and Mrs. Ralph Connor. Through the efforts of these heirs, the Wisconsin Dells was made available to the Wisconsin Alumni Research Foundation. Eventually, the income from the property will become part of the Foundation's annual gift to the University of Wisconsin for research. The acquisition of such a well known portion of Wisconsin's natural landscape seemed to furnish an appropriate occasion for an assessment of the value of the University of Wisconsin's research program to the conservation of the State's natural heritage of field and forest, lake and stream. It is hoped this book, in some measure, accomplishes that task.

Mrs. Lois Crandall Musson and the Crandall pine plantation at the Dells . . .

To those who have furthered, in any way whatever, the research programs that provide our working knowledge of Wisconsin's renewable resources—lake and stream, field and forest—and to those who may be inspired to support these programs in the future, this volume is respectfully dedicated.

Without freedom on the part of scientists and students for the expenditure of many hours and days in field and laboratory research, and without friendly and helping hands everywhere, few research projects could be a success.

INTRODUCTION

IF THERE IS A SINGLE THEME RUNNING THROUGH THIS BOOK, IT IS THAT RESEARCH has done much to help solve many of the problems posed by the need to manage wisely and well the natural, renewable resources of Wisconsin.

Renewable resources are those that rebuild themselves if given the opportunity. In this category fall such things as soil, forests, wildlife, and the aquatic resources, water and fish. Renewable resources are those that man most often taps for food, shelter, and recreation. The non-renewable resources—ores, minerals, oil, and coal—are those he exploits to build and operate industry.

Once gone, the non-renewable resources are gone forever. The renewable resources, with proper management, will last as long as the earth continues to exist. And they must last as long as man continues to inhabit the earth, for without them he cannot survive. The word *management* rather than *conservation* applies most aptly to them. They are not meant to be conserved, as coal or oil should be. They are meant to be used. But they must be so managed that they will continue to renew themselves, and continue to produce a harvestable surplus, year after year, century following century. Research has pointed the way by which this can be accomplished for many resources, but many basic principles governing resource use have yet, undoubtedly, to be revealed. Only our investment in future research will insure that the earth continues to be bountiful—as it must as world populations soar.

The research projects reported here were conducted by University of Wisconsin scientists and research assistants (graduate students) with the exception of a few mentioned in the sections on early history, and these were included to provide historical perspective. In a few instances, research that began at the University was continued elsewhere. Many students have been employed by the Wisconsin Conservation Department, during study or after graduation, and many research projects have been—and are—carried on jointly by the Department and the University.

The research is the work of hundreds of individuals, each of whom contributed to the existing knowledge of Wisconsin's resources. It is unfortunate that not all are mentioned, but a roster of those who have taken part in the research would have filled the book.

The quotation at the beginning of this volume is from an address by William Vogt, distinguished scientist and conservation philosopher, delivered on the occasion of the University's Centennial. It describes Wisconsin's role in the development of the science of ecology and the applied science of resource management. We can work to see that Wisconsin's leadership continues. It will be for the benefit of men and women everywhere, not only in Wisconsin but

throughout the world. Resources are becoming more important. They are being used in increasing volume. They are, ultimately, the determinants of our nation's future.

The Wisconsin Alumni Research Foundation, since its founding in 1925, has been a major contributor to the University of Wisconsin's record of achievement in research in the natural sciences. In addition to the grants from the Foundation, Wisconsin research programs are supported at the present time by grants from hundreds of the nation's leading industries, from the federal government, and from all major foundations. With these investments in progress, Wisconsin's program has expanded in many directions. But much of Wisconsin's scientific strength has been built upon the financial core provided by the Wisconsin Alumni Research Foundation's annual grant in support of research. At the present writing, this grant exceeds a million dollars a year. Administered by the Research Committee of the University's Graduate School, the grant is used to finance explorations in many fields of science. These explorations are the advance guard of progress. The scientific pioneer plays as important a role in human affairs as the pioneer who opens new lands. It was to describe in some detail the importance of research in the wise management of renewable resources that this book was planned and written.

It might be pointed out that research is a continuing effort. As far as we can see today, there will never be a time when the acquisition of new knowledge will not be a useful pursuit for man. Each new finding, each fact acquired, has its own particular practical use; it is often most useful for opening new doors for further explorations into the unknown. Man's search into the mysteries of the universe and of life will go on; it is his nature that he must explore. The advances that have resulted from this quest in the past 300 years are but a portent of the future achievements, both practical and philosophic, that are to be had.

Madison, Wisconsin
September, 1956

ACKNOWLEDGEMENTS

THE CHAPTERS IN THIS VOLUME WERE WRITTEN TO DESCRIBE THE RESEARCH FINDINGS of the hundreds of University of Wisconsin scientists and graduate students, past and present, and it is hoped that, in a sense, this book will be considered a part of that work. It is manifestly impossible to mention each individual who has contributed to knowledge of Wisconsin's resources, but it has been possible to list some of them by including references to published scientific papers at the end of each chapter.

Among those who read at least portions of the manuscript to insure accuracy were Daniel M. Benjamin, Kenneth P. Buchholtz, Noble Clark, Grant Cottam, John T. Curtis, John T. Emlen, Gerald C. Gerloff, Frederick N. Hamerstrom, Jr., Frances Hamerstrom, Arthur D. Hasler, Joseph J. Hickey, James E. Kuntz, Robert A. McCabe, Robert J. Muckenhirn, Roland K. Meyer, Albert J. Riker, Walter A. Rowlands, William B. Sarles, Roy D. Shenefelt, Folke Skoog, Warren J. Wisby, and Otto R. Zeasman.

Particular thanks are due to Gerhard R. Schulz and the staff of the University of Wisconsin Photographic Laboratory; to the Wisconsin Conservation Department for a number of bird and animal photographs; to George J. Socha of the University Zoology Department and Norman Elke of Rhinelander, who rendered special photographic assistance when it was much appreciated; and to the many persons who extended the courtesy of assistance in finding photographs or permitting their use. Fredrik T. Thwaites made a special effort to prepare a map of the glacial geology of the State. The early-day map that appears inside the cover was provided through the courtesy of the State Historical Society. Photograph credit lines appear at the end of the volume. Vivien Hone read the manuscript and proofs to help correct errors. Marion Oleson typed the manuscript.

Special acknowledgment is due the trustees and officers of the Wisconsin Alumni Research Foundation, University President Edwin B. Fred, and Conrad A. Elvehjem, dean of the Graduate School and chairman of the Research Committee of the University, for their support of the project.

Particular thanks are due also to Robert J. Dicke, former secretary-treasurer of the Wisconsin Academy of Sciences, Arts, and Letters, who collected all of the papers by Wisconsin scientists which have appeared in the Academy *Transactions*, and made them available to the author.

A former Academy president, A. W. Schorger, has written: "It is my belief that the Wisconsin Academy, particularly through members in the various educational institutions throughout the State, should provide scientific data that can be used as a basis for formulating public policy on the conservation and utilization of our local natural resources." This book will show that the Academy, in the past, has served well in this capacity, and that its future contributions can be even greater.

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"Persistent research should give us a body of knowledge upon which we can finally come to some common and reasonable agreement and upon which we can base our decisions."

—Paul B. Sears

Prologue

THE SENSE OF TIME AND PLACE

Wisconsin was carved from wilderness a century ago by hardy people who hoped to find, and build, in a new land the things no longer available in an old one. They found here, between the Mississippi River and the Great Lakes, a land that was naturally rich. The arts they brought with them and the sciences developed since have helped erect an economy that supports nearly four million persons in relatively stable prosperity. Today, every man engaged in farming supplies food for himself and 20 other persons (in this country and abroad) on land that in its primitive condition was able to support but few.

Wheat and the axe first changed the face of Wisconsin. The State's wheat crop in 1856 was 28,000,000 bushels. A thousand sawmills once turned out two and a half billion board feet of lumber each year, and forest industries became established in the North; cities and towns grew wherever transportation, power, raw materials, and people could be found to supply and operate factories.

But the timber was finally gone; and wheat moved westward to the plains. Wisconsin became a dairy state. Today, agriculture must be considered the State's basic activity, although financial figures would indicate that Wisconsin is more industrial than agricultural.

Whatever the figures show, the land and its varied uses constitute the State's basic resource, and research has brought Wisconsin's farms to enormous levels of productivity. But we have renewable resources we have not exploited fully. Woodlots and wildlife can be part of erosion control in the southern part of the State; game, wildlife, and recreation can become even more important products of northern forestry. In these fields, research has shown—or eventually will show—what can and should be done; only the economics of practical programs remain to be worked out. It is important that wildlife management, like forestry and agriculture, be practiced in such a way that the producer is rewarded and the consumer bears the expense. The question was asked recently: "Why can't we find ways of getting together to work out these much desired improvements in outdoor Wisconsin, and in the protection we provide for the State's most valuable resource—the soil on which our agriculture depends?" The answer, of course, is that we can, if we make the effort.

Research has done much to help create an efficient and productive farming industry in the State. It is just as necessary to have the aid of science in making the most of the State's water, wildlife, and out-of-doors for recreational and cul-

tural purposes. This volume concerns the useful, and we hope interesting, contributions made by research to our knowledge of woods and waters, birds, animals, and fish. The research conducted thus far is but a beginning. There are many things still that need to be learned; we shall learn them through our research programs. "Our native plants, trees, birds, animals, and fish inevitably face a different environment today than before the white men came to Wisconsin," the director of the University's Agricultural Experiment Station pointed out recently. "Our challenge, which research can help us to meet, is to find ways of enjoying the benefits of our modern agriculture and urban industry, and at the same time preserve, protect, and promote the continued existence of the plants and animals which were here before us, and that are resources which can continue to make enormous contributions to our welfare if we but use them wisely."

PART I

"We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. There are tens of thousands of years in the future."

—R. P. Feynman

"It is by now a truism that the American frontier did not cease to exist when the covered wagons halted on the shores of the Pacific. In its wake followed a scientific frontier, which opened up the resources of the new-found lands to human understanding in quite the same sense, and in no less degree, than the geographical frontier opened them to human occupancy."

—ALDO LEOPOLD

Chapter One

THE LIMITLESS WILDERNESS

WHEN THE EARLY EXPLORERS—NICOLET, GROSEILLIERS AND RADISSON, PERROT—first saw the vast forests, prairies, the lakes, and the swamps of the region known as Wisconsin, their impressions were of limitless wealth. The abundance of fur accounted for much of the interest in the region on the part of the early French trappers and traders. The abundance of timber was to account for its subsequent economic development. Initial impressions may have been of limitless wealth, but within two centuries from the time the first white man canoed along her waters, the notion that Wisconsin harbored an inexhaustible supply of game and timber had been quietly dispelled.

Each explorer saw the new lands in a different light, and many wrote descriptions in their journals that later proved inaccurate. Writing in 1667 of his travels in northern Wisconsin, Nicholas Perrot said "it is nothing but lakes and marshes." He added that the Sioux were inaccessible in so swampy a country, and protected from war parties of other tribes because they could travel everywhere by canoe. The idea that northern Wisconsin and the Upper Peninsula of Michigan were a vast swamp gained wide acceptance. As late as 1852, a speaker at the annual meeting of the Wisconsin Agricultural Society noted that northern Wisconsin was slightly known, but he did attempt to correct a report of a U.S. War Department official who described the entire region as "impassable swamp."

Of southern Wisconsin, Louis Hennepin, a Flemish missionary, wrote in 1698 that "we could not sufficiently admire the extent of these vast countries, and the charming lands through which we passed, which lie all untilled . . . Our countrymen would do well to think of it, and go and plant themselves in this fine country . . ."

By the middle of the 1800s, settlement of southern Wisconsin was well advanced and northern logging had begun. It was clearly apparent by the early 1860s that cutting of the State's timber resource was proceeding at an alarming rate, and three leading citizens of the new State—Increase A. Lapham, Judge J. G. Knapp, and Hans Crocker—were requested by the State Legislature to prepare a detailed report of "the disastrous effects of the destruction of forest trees now going on so rapidly."

With remarkable insight for their time, these men reported that "clearing away the forests diminishes the flow of water from springs, increases the suddenness

and magnitude of floods and torrents, washes away the soil, exposes the State and all its inhabitants to the biting and blighting effects of the winds which will sweep over the surface with unabated violence, causes snow to accumulate in drifts, leaving portions bare and unprotected while other portions are buried in accumulated masses of snow, and loosens sandy soil so that it will be blown away by the wind."

Despite the fact that 5,000 copies of the report were printed and distributed, it was not until 1878 that a substantial attempt was made to save some of the native timber resources of the State. In that year, 50,000 acres of forest in Vilas, Oneida, and Iron Counties were incorporated into a state park timber reserve. Within 20 years, however, this, too, was being marketed.

In 1898, Filibert Roth of the U.S. Department of Agriculture reported: "More than one million acres have been cleared [in northern Wisconsin] and put under cultivation. During 40 years of lumbering nearly the entire territory has been logged over. . . The fires following all logging operations or starting on new clearings of the settler have done much to change these woods. Nearly half the territory has been burned over at least once, about three million acres are without any forest cover whatever."

In addition to the commercial interest in Wisconsin's resources, there was actually a great deal of early interest in scientific work, much of it by men whose abilities were remarkable and whose notes and scientific papers, fortunately, have been preserved. Judge Knapp was one of those rare individuals whose consuming interest and acute insight into the workings of nature surmount a lack of formal training, and whose breadth of vision produced original conceptions that we are beginning to fully appreciate only today.

It is difficult to comprehend the difficulties under which the early naturalists worked. They possessed only crude, verbal descriptions of many of the species of plants and animals; there existed none of the guide books now so widely used, with colored photographs, drawings, and artificial keys by which species can be easily identified. Many plants and animals were new to these scientists—a large number were actually new to science—and all of the early naturalists described as new many species which actually were not. It is not surprising that these naturalists made errors, but it is surprising that they made so few.

Knapp saw that four distinct vegetation types existed in Wisconsin. He put forth in his published scientific papers the belief that these were, at least in part, the result of differences in climate. Earlier in the century, the great German scientist, Humboldt, had dispelled for good the notion that all areas of the globe of equal latitude have comparable climates. Humboldt had been the first to draw isotherm lines on the map of the world, joining places with the same average temperatures. But why, asked Knapp, when the "same lines of latitude, and the same isotherms, pass through both Wisconsin and Michigan, do peaches, pears, and tender apple trees do well in Michigan but fail in Wisconsin"?

Knapp found his answer in the isocheims—the winter lines. The 20-degree isocheim runs from the southwest to northeast corners of Wisconsin. Plants that cannot stand severe winters will grow east of the line but not west of it. Knapp also saw that "the characters and changes in our tree belts correspond almost exactly with the isothermal lines of the State," and he divided the State into four broad forest regions: (1) The belt that "occupies the whole north portion of the State, and covers nearly one-half its surface" in which are found native white pine, fir, hemlock, spruce, white cedar, birch, black ash, and where maples, elms, and oak grow only on the driest ridges. (2) The next belt to the south where "timber is generally deciduous . . . to which must be added the bur oak, white ash, butternut, and hickory. The oaks, maples, and elms increase in number and size." (3) The belt of oak-openings and prairie in which are found white oaks, maples, elms, butternut, shag-bark hickory, and sometimes black walnut. "The white and yellow birch are largely gone, as are the hemlocks, cedars, spruces, and firs." (4) The southernmost belt, which Knapp believed to be so typical that he named it the "Wisconsin Belt," composed of alternate woods and prairies.

How advanced these ideas were for their time is revealed by one other notation Knapp made in his writings. He urged people new to this land to adopt customs fitted to it:

> "People may carry their language, modes of dress, and some of their seeds with them from one country to another, but they cannot carry the climate. New conditions are here, and old rules have and must fail. Hence we see men here ditch lands already partched . . . lay drain tile in gravel and sand beds where water cannot accumulate. . . They rear their trees in nurseries according to rule . . . and the trees perish. . . They see all these things, yet never suspect that the peculiarities of climate have anything to do with it."

Knapp also saw the need for what we have come to call research:

> "Scarcely anything has yet been done in the examination of vegetation. Yet, if we think how they are exposed to every change, there appears to be no line of examination that would be attended with more important results to the interest of the agriculturist . . . or from which the scientific could gain more absolute knowledge. I can only hope that men and means will yet be found to enter upon this field, and after full investigation, point out the utility."

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"What is conservation, anyway? But are we not learning, at last, that Man is not a being apart, but rather one of the species making up the interrelated biota of the whole earth? And that eventually we must cease our puerile boasts of our 'Conquest of Nature' and learn better to adapt our own lives to Nature?"

—Norman C. Fassett

Chapter Two

THE CORNERSTONE IS LAID

Nicolet came to Wisconsin seeking a route to China through the Great Lakes and Green Bay. In his notes he refers to a single Wisconsin plant species, wild rice, and describes it as a staple food for the Indians of Green Bay. In 1660 the Jesuit, René Ménard, reported that in central Wisconsin, "tripe de roche, a kind of moss found on the rocks, when mixed with water served many times to keep the company from starving." The bark of birch, basswood, oak, and acorns, raspberries, and wild rice are mentioned by Ménard as having been used for food. While the early explorers named or described one or two species of plants—usually those noted for some useful characteristic—the first naturalists in the State made a serious effort to obtain complete lists of the plants that grew in the region. The latter half of the 19th century marked the beginning of accurate and scientific observation. It was amazingly accurate in many respects. Some of the naturalists of the day clearly stated basic principles upon which modern research and conservation practice are based.

Increase A. Lapham was among the most unusual of these early naturalists. He was exceedingly shy, yet his influence was widely felt, and his work ranks with the most important of the time. He studied and catalogued 949 species of plants found in the area around Milwaukee, of which 70 were grasses, and he published his list in 1852. The next year he expanded the list of grasses to 149, and by 1885 he had described scientifically 60 forest trees native to the State.

Such descriptive lists of species are the raw material for research on forests and other vegetation types, and for the development of methods best suited to propagate and protect useful species. Lapham wrote that Wisconsin's pineries, thick hardwood forests, oak openings, and prairies "may each be considered as distinct botanical districts . . . affording plants peculiar to themselves, and giving great richness and variety to our flora." He also saw that grasses are "one of the most important means of keeping up the natural fertility of the earth" and predicted the future importance of rotation and of grassland farming. Lapham wrote that some lands maintained in grass might be more productive than if cropped in grain, and "a certain succession of different crops will, in a great measure, prevent the exhaustion of the soil."

The Wisconsin naturalists who made serious efforts to obtain complete lists of plants growing in various areas of the State are too numerous to name, but in 1883, G. D. Swezey published his "Plants of Wisconsin" as part of an ambitious

Specimens of each plant species growing in the State are collected in the herbarium . . .

survey of Wisconsin's natural resources conducted under the direction of T. C. Chamberlin (who became University president in 1887) and bearing the collective title *Geology of Wisconsin.* Swezey listed some 1,500 plant species found in the State.

Then in 1900, L. S. Cheney wrote a comprehensive historical review of the work done up to that time, naming the most important workers and citing their published reports. From that time until the early 1930s, Cheney and Dr. John Jefferson Davis seem to have been nearly alone in their interest in the vegetation native to the State. Although he held a medical degree and had practiced medicine in Racine for a number of years, Dr. Davis came to the University in 1911 to serve as curator of the University's herbarium. He continued as curator until his death in 1937, and he left a large scientific library and his botanical collection to the University. Between Cheney and Davis, the flora of both northern and southern Wisconsin were thoroughly surveyed, and hundreds of specimens these men collected are still to be found in University herbarium cabinets.

For some reason, with increased lumbering activities, botanical and forest research went into eclipse. Only when the timber was gone, and much of the North proved unsuited to crops, did the disastrous result of the neglect become apparent. Lapham had predicted as early as 1885 that Wisconsin would need a knowledge of forest management. "Nature is already making efforts to prevent the disasters we are thoughtlessly bringing upon ourselves by the destruction of the forests," he wrote. "But it would be idle to rely entirely upon this natural restoration of the forests; we must sooner or later commence the cultivation of wood, or suffer very much from the neglect."

The cultivation of wood, however, is not an easy task, and even today our knowledge of how to grow some of the most valuable species on a sustaining basis is incomplete. There are two reasons which probably account for the scientific inactivity between 1900 and 1930. First, most of the early lumbering interests failed to realize that research would be needed to solve problems that arise when timber has to be grown. Second, there was a lack of scientists trained and equipped to conduct research in the forests.

By the early 1930s, however, this was changing. In 1929, Norman C. Fassett published the first of a series of scientific studies on Wisconsin vegetation that numbered 37 separate studies by the time of his death in 1953. Entitled collectively "Preliminary Reports on the Flora of Wisconsin," the series was published in the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters.* Fassett and his students mapped the areas in which each plant species is found in the State.

In initiating his series, Fassett recognized the fact that the work of serious amateurs would be essential to its success. "The professional botanist may visit any given locality, and perhaps find a fair proportion of the plants in flower or fruit [necessary for accurate identification] at the particular time, but only the

local botanist, watching the same region throughout the year and from year to year, can have a true conception of the local flora. By presenting graphically the known range of each plant, it is hoped to show the amateur how he can help fill the gaps in our knowledge of these species."

To the many amateurs who contributed to knowledge of Wisconsin's vegetation, and to the relatively few professional botanists who worked on the more difficult groups (such as the fungi, mosses, and lichens) belongs enormous credit for having established the foundations. They achieved little recognition beyond that provided by their colleagues, but without the accurate information they provided, the work of those to come—who would begin to establish the "why's" and "how's" of plant growth and forest management—would have been much more difficult and long delayed if not impossible entirely.

John T. Curtis, who directs the current program of research on Wisconsin's vegetation, has said:

> "Beginning in 1929 and continuing until 1953, Norman C. Fassett and his students issued a series of 37 preliminary reports on the flora of Wisconsin which discussed and mapped the plants of the State, family by family. Only a few families remain to be completed. This accurate information on the kinds of plants and their distribution formed a strong basis for a revival in interest in the vegetation of the State. The use of quantitative methods and extensive sampling have resulted in a series of papers on the forest and prairie types of the State in the period since 1949. This work has all been done at the University of Wisconsin, with the support of the Wisconsin Alumni Research Foundation. When the projected study is completed in the near future, we shall know more about the vegetation of Wisconsin than is known about the vegetation of any other state. One of the major reasons for this superiority is the detailed information presented by the early investigators which permitted a ready appreciation of the successional changes which have occurred in the intervening century and thus provided a dynamic basis for the modern students."

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"The second hundred years will prove our mettle far more severely than the past century. The test will come when a decent living is required of limited resources. . . To a nation accustomed to luxuries far beyond the wildest dreams of less fortunate people, shortage of resources will creep upon it insidiously, and finally as a very galling and frightful fact of life. Capital, labor, and government, all can be indicted for the continuing destruction and waste that is slowly and surely sapping our strength. . . The rank and file of the American people do not have the basic understanding of the conservation problems which are facing them."

—Ernest Swift

Chapter Three

WEB AND ROCK

One modern astrophysical theory holds that some two or three billion years ago the earth and other planets were torn from the sun by the enormous force of gravity exerted by a passing star. This star—in reality another sun like our own—pulled away a great tide of flaming material and left it spinning and condensing into the bodies we know as planets. These bodies cooled more rapidly than the parent sun because they were smaller, but also probably because of yet little-understood chemical and physical laws that tend to keep the flames of burning suns hot.

As it cooled, the earth's crust underwent many changes. Mountains were thrust up in wrinkles like the surface of a dried orange, and vast glaciers advanced and receded from the poles again and again as the earth wobbled on its axis, exposing first one end and then the other to warm radiation from the sun. These changes are still taking place, with all but imperceptable slowness, and from them we reckon the age of earth and sky around us.

A fundamental law of science states that energy tends to establish an equilibrium. A rolling ball harbors energy that is lost to friction until the ball stops. The energy of sunlight evaporates water from the sea and is found again in rain that falls and wears away mountains. Energy is never destroyed, nor is it created, but it is exchanged again and again, and modern physical theory points out that energy can be turned into mass and mass to energy. But once equilibrium has been reached, matter and its energy remain in balance until new events once again set off chains of action and reaction.

Except in the polar regions and the most arid of deserts, the surface of the earth is in a fascinating state of energy imbalance. Many things contribute to this state. The continual supply of heat from the sun is one. The nature of the earth's atmosphere is another. The sun warms the earth, winds carry moisture across the

continents, dropping it over fields and forests and the headwaters of streams and rivers. The energy held in chemical compounds of rock, sand, and soil is slowly released, then tapped by vegetation.

Living things gather and store energy in tissues, but they continually liberate it in their quest for food and shelter. It finally escapes in death and decay, but is regained by other forms of life and by the new generations that rise from the old. All life is caught in the relentless struggle to capture and save some of the energy of sun and soil before it runs finally downhill, to be lost in the great rivers that flow toward the last equilibrium of the world's ocean depths.

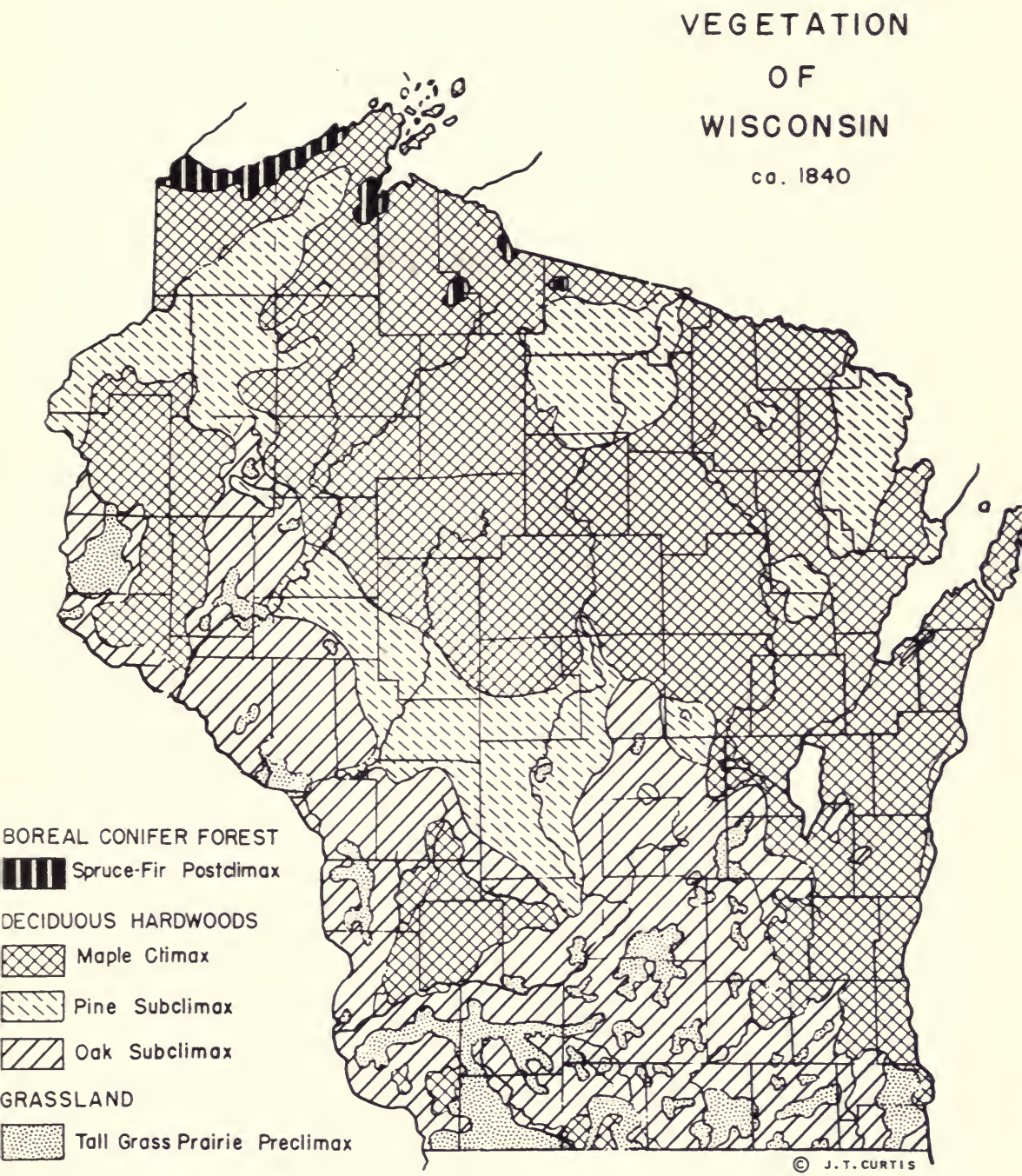
Aldo Leopold wrote:

> "All land represents a downhill flow of nutrients from the hills to the sea. . . Plants and animals suck nutrients out of the soil and air and pump them upward through the food chains; the gravity of death spills them back into the soil and air. . . There is a deficit in uphill transport, which is met by the decomposition of rocks. . . The continuity and stability of inland [plant and animal] communities probably depend on this retardation and storage."

The plant species that compose the native vegetation of any region are the result of ceaseless evolution and adaptation to the conditions that prevail. The natural vegetation of any area represents the best adaptation of plants to soils. We can be fairly certain that natural vegetation is a most efficient vegetation from the standpoint of the survival of the species present and from that of entrapment and damming of energy. The destruction of the native communities results in drastically altered soil and other environmental conditions. Soil nutrient resources are lowered. Water balances are upset. Watersheds erode.

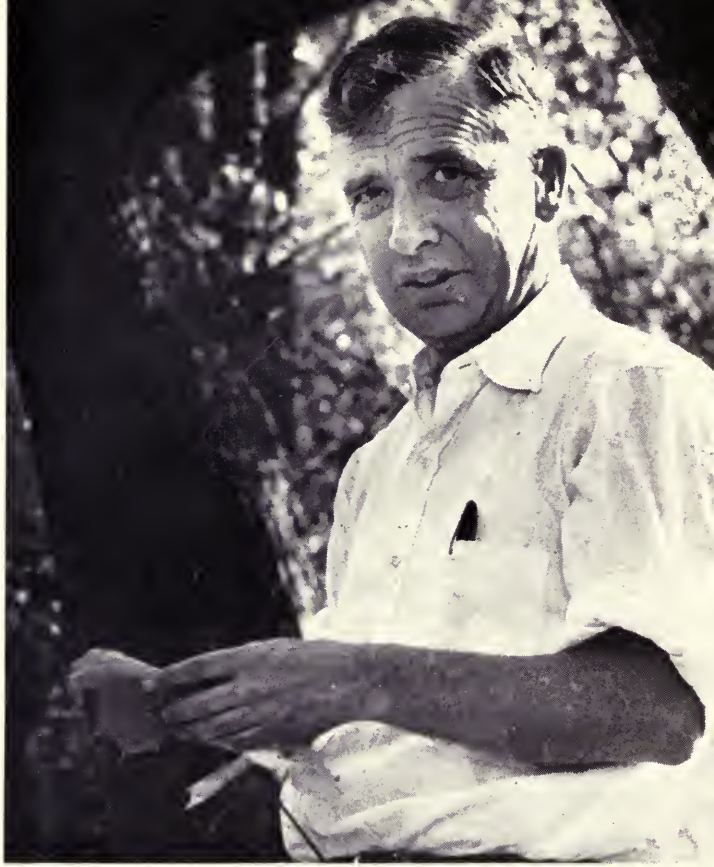
The distribution of vegetation types across the faces of the continents is determined by climate and topography, by soils, temperature, and rainfall, and the influences upon these of mountains, ocean currents, and winds. In 1910, Charles R. Van Hise (who had become University president in 1903) gave his basic division of American landforms: the Atlantic and Gulf plains; the Eastern ancient plateaus; the Appalachians, Alleghenies, and Ozarks; the Lake plains; the Prairie plains; the Great plains; the Rocky Mountains and Western plateaus; and the Pacific region. These landforms, with their climates, soils, and other individual physical attributes, formed the environment in which the evolution of native plant species and associations took place. The original forests and grasslands of North America can be classified into seven great divisions: the tall-grass prairies, the short-grass prairies, the great northern boreal forest, the central deciduous forest, the southern forest, the Rocky Mountain forest, and the Pacific forest.

We have in our western prairies some of the finest examples of what happens when native balances are upset. Prairie grasses will utilize and absorb water when it is available, then turn dry and parched to survive the arid season. No other plants can protect the soil so well from erosion and drought, nor be as resistant to permanent damage from moderate grazing. A similar situation can be found in many of the areas of northern Wisconsin. Here, only the native forest



"Southwest of a line from Milwaukee to Hudson, the greater part of Wisconsin a century ago was covered by prairie and oak opening. The oak openings were maintained by periodic Indian fires, spreading from the adjacent prairies. Early white settlers took up the prairie land for their crops, thus destroying the prairies and ending the fires. In the absence of this controlling agent, the oak openings began to fill with dense oak forest, the new trees coming from both acorns and oak grubs."

—John T. Curtis



The late Norman C. Fassett, professor of botany and curator of the University of Wisconsin Herbarium, 1937–1954.

communities are capable of protecting the soil from depletion, and only forestry can be practiced profitably over extended periods of time.

The potentialities of many lands of the world are not known because there exists no record of what these lands were like when they grew the plants best suited to them. But fortunately, there remain in Wisconsin isolated examples of most of the pre-settlement vegetation types, and these have been studied intensively by scientists and will be studied for many years to come.

Norman C. Fassett pointed out:

> "It is not for the sake of sentiment alone that we should seek out the few remaining relics of Wisconsin's original vegetation and try to preserve them. These relics not only picture for us and our children the land where our forebearers pioneered. They represent the raw material with which we still work, the soils and their biota from which we all get our living. Intelligent utilization of these raw materials requires us to keep, not only for ourselves but even more for the students who will follow us, these examples of the original Wisconsin that we have so profoundly altered."

It is the primary aim of the scientific study of natural, renewable resources to provide the knowledge by which we can achieve intelligent use of land. Intelligent use requires that man's needs be supplied on a sustained yield basis, and that the carrying capacity of the land be maintained for the longest possible period of time. Too often, as Aldo Leopold wrote, man attempts to "rebuild the earth—without plan, without knowledge of its properties, and without under-

standing of the increasingly coarse and powerful tools which science has placed at our disposal."

It is a long and arduous scientific undertaking to reveal and understand the systems of checks and balances that nature has created in the webs that bind living things together, to sunlight, water, and soil. Yet it is important that they be understood or the resources upon which we depend will slowly vanish. They have already vanished in many parts of the world that were once rich in soils and forests. The land in parts of Spain, the Middle East, parts of Africa and China furnishes some of the best examples of what happens when forests are removed and soil exploited relentlessly. It is probably true that, in these countries, it was not possible to know what would happen following exploitation. But today the examples are there for all to see. They provide stark evidence that the principles of resource management must be applied, for the only alternative is disaster. John T. Curtis adds:

> "To achieve it in our time, and while time and the necessary resources still remain, is a difficult task, made more so by the great numbers of city dwellers who are remote from the land and its needs. If we succeed in doing so, it will be an everlasting credit to the nation's wisdom and ingenuity, for elsewhere this wisdom has been gained only after the disastrous nature of the alternative had become apparent to all."

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Contoured fields and hillside woodlots in Coon Valley . . . good erosion control measures.

"Coon Valley is one of the innumerable little units of the Mississippi Valley which collectively fill the national dinner pail. Its particular contribution is butterfat, tobacco, and scenery. When the cows which make the butter were first turned out upon the hills which comprise the scenery, everything was all right because there were more hills than cows, and because the soil still retained the humus which the wilderness vegetation through the centuries had built up. The trout streams ran clear, deep, narrow, and full. They seldom overflowed. This is proven by the fact that the first settlers stacked their hay on the creekbanks, a procedure now quite unthinkable. The deep loam of even the steepest fields and pastures showed never a gully, being able to take on any rain as it came, and turn it either upward into crops, or downward into perennial springs."

—Aldo Leopold

"There is no escape from the fact that the future welfare of people—both Americans and those who reside in other lands—is dependent upon an adequate supply of productive land. The greatest enemies of nations are not other nations, but the human ignorance, the selfishness and the injustices which are largely responsible for widespread hunger, poverty, and disease. . . In a very literal sense, soil resources have become the determining factor as regards the kind of a life which will be possible for mankind in the decades ahead."

—NOBLE CLARK

Chapter Four

BIRTH OF THE SOIL

IN THE FIRST CENTURY B.C., THE POET VIRGIL WROTE IN HIS *The Georgics*, A LONG poem describing the earth and its crops: "Nor indeed can all soils bear things. By riversides willows grow, and alders in thick swamps, barren mountain-ashes on rocky hills; on the seashore myrtle thickets flourish best; and the god of the vine loves open slopes, as yew [cedar] trees do the freezing north. . ."

It has, thus, long been known that differences in soil, slope, and climate must be taken into account, both by those whose interest is in growing and harvesting crops and those who seek the wealth to be found in native species of field and forest. It was believed initially—and until relatively recently—that differences in soil were to be explained by the science of geology; that one soil differed from another because of differences in the rocks and sand of which it was composed. That plants themselves build soil, and that different plant types build different soil types, was a discovery long in coming.

Wisconsin's topography is, to a considerable extent, the product of glaciation. In the Pleistocene Age—the geologic era just prior to our own—glaciers stretched outward across the face of the land and then retreated on at least four different occasions. They left scars in the form of moraine and drumlin, and a varied assortment of geological structures and strata intelligible only to glacial geologists. For many years, scientists have studied these distinctive shapes in the Wisconsin landscape, and the rocks and sands beneath them, along with the evidences of weathering and erosion that give some indication of age. A buried pre-glacial forest was discovered at Two Creeks in northeastern Wisconsin, and other scattered remnants of ancient life have been found elsewhere. With radiocarbon dating—one of the new tools of the atomic age—scientists have established the probable date at which these ancient bits of wood were buried. The estimates place the last advance of a glacier at some 11,000 to 12,000 years ago.

Botanists have taken samples of the material found at different depths in peat bogs and in these samples have found well-preserved pollen from tree species that grew many thousands of years ago. The first trees to invade the land in northern Wisconsin after the retreat of the last glacier were spruce and fir. As climate moderated and favorable soil was built beneath the spruce and fir forests,

the pines began to replace these pioneer species. Still later, the hemlocks, birches, and other species took over the land as humus became richer and forest shade deeper.

Southern Wisconsin was neither glaciated as frequently as the northern half of the State nor did it lie as long under the influence of the advancing and retreating ice. Most of southwestern Wisconsin was not glaciated at all. Here, the Driftless Area (drift refers to deposits of sand and gravel left by glaciers) comprises a region of well-worn stream and river beds and rugged terrain unsmoothed by crushing layers of ice. In contrast, the glaciated portion of the State is characterized by rolling hills and young rivers. In the far North, the last glacier left large areas of what is known as pitted outwash. The pits have filled with water, forming the lakes for which northern Wisconsin is famous. By geological standards, these lakes are comparatively shallow. The deepest of those in the northern part of the State is Trout Lake, 115 feet deep, the site of a University Hydrobiology Laboratory. The gentle slopes and sandy beaches of many northern lakes render them especially valuable for resorts and recreation.

The source of Wisconsin's water is rainfall and snow. Of the water that falls, some evaporates, some is retained in surface soil, and the remainder filters downward to enter the water table or runs off in streams, eventually flowing into the Great Lakes or the Mississippi River. Since Wisconsin is abundantly endowed with lakes, streams, and a high average rainfall, the State's ground water supply problems are confined largely to major cities. In some of these, the level of water in deep wells has steadily declined, and shortages may become serious in the future. In 1945, the Wisconsin Legislature authorized the University to cooperate with the U.S. Geological Survey in a study of ground water supplies throughout the State. Geologists conducting the survey have confined their studies largely to problem areas, but eventually the ground water supplies of the entire State will have been surveyed and mapped.

Water and soil are basic resources. One without the other is useless. Research has been conducted at the University for many years on soil; on the minerals, organic material, water, dissolved air, and living organisms found in soil. The published scientific papers on soil alone would fill many volumes and they number in the hundreds. Franklin H. King, a pioneer soil scientist, was the first in the world to hold a professorship of agricultural physics, created at Wisconsin in 1888, and King's early studies on the role of water in the soil and the physical properties of the particles that compose soil rank with the most important of his time. He also wrote one of the first descriptions of wind erosion on cropland, and he proposed various wind erosion control measures that are still in use.

Emil Truog pioneered in soil testing, work which opened the way for application of lime to Wisconsin's acid soils, providing a basis for the expansion of acreage devoted to alfalfa. In 1879, T. C. Chamberlin wrote a general description of the soils of Wisconsin and included the first soils map of the State in his *Geology of Wisconsin*. Since that time, some 40 Wisconsin counties have been mapped

in detail by University soil scientists, and the soils of many others have been surveyed in part.

Soil unprotected by foliage and the root systems of plants is subject to accelerated erosion, certainly one of the most serious of the drains upon natural resources. Soil is a basic wealth, and when both it and rainwater rush in a torrent down hillsides and streams, very little of value ever remains. Poorly managed cropland is subject to erosion to a marked degree. Two University scientists, R. J. Muckenhirn and O. R. Zeasman, found in 1940 that a third of Wisconsin's cropland has lost a layer of soil as deep as a plowshare cuts, and a fourth of the State's pastureland has lost an equal amount. In southwestern Wisconsin, the loss has been much greater, with more than 60 per cent of the cropland having lost its richest layer of soil, or more, to erosion.

Wisconsin scientists have studied many aspects of erosion, among them, the rate at which plant nutrients in soil are lost by rainwater run-off and by leaching. They were among the first to show by direct experiment that the force with which rain falls on unprotected soil is a factor in erosion, and that the impact of raindrops often starts fine soil particles on their way downslope in run-off water. These are basic processes of erosion, and an understanding of them has led to the development of many practical erosion control techniques.

When declines were noted in the productivity of permanent pastures in the State, Wisconsin scientists worked out methods for pasture renovation. They also showed that wooded pastures produce a fifth as much forage as open pasture and a tenth as much as renovated pasture. H. L. Ahlgren, M. L. Wall, Muckenhirn, and J. M. Sund wrote:

> "Continued grazing of wooded areas on gray-brown podzolic soils in the northern part of the Mississippi Valley is hardly worth-while, especially since grazing will ultimately destroy the woods. However, the results do not justify the conclusion that wooded pastures should be indiscriminately cleared to obtain higher yields of forage. Wise application of the findings of this study would lead to selection, clearing, and improvement of the best land available for pasture and the fencing out of the remainder as permanent farmwoods. . . Of each 11½ acres in wooded pasture at present, one acre, if well selected and renovated, would produce enough forage to enable the farmer to fence out the remaining 10½ acres for a permanent woodlot without reducing his supply of pasturage. . . The advantages of maintaining and managing a farmwoods as a source of fuel, fence posts, and lumber, and as a means for the preservation of wildlife as well as for recreational and aesthetic values, reinforce the economic arguments for pasture improvement."

In the fall of 1933, soil experts from the University of Wisconsin and the federal Upper Mississippi Valley Conservation Experiment Station near La Crosse undertook the first large-scale demonstration of what soil and water conservation can accomplish. The demonstration area was Coon Valley, of which Aldo Leopold once wrote: "It is one of a thousand farm communities which, through the abuse of its originally rich soil, has created the Mississippi flood problem, the navigation problem, the overproduction problem, and the problem of its own future continuity." The Coon Valley Soil Conservation Project did not mark the first time soil erosion measures had been instituted, even in Coon Valley. In the late 1800s. Swiss farmers who settled in Mormon Coulee near Coon Valley began

using strip cropping on sloping fields, and recent studies of their fields have shown that they accomplished a definite saving of soil in comparison with other areas.

The Coon Valley project, however, was instituted to control soil erosion on a scale hitherto never attempted, and it was designed to convince one and all that the evils of erosion could be combatted successfully at their source. In the project, labor, wire, seed, lime, and planting stock were provided by federal agencies to farmers who agreed to a five-year trial of soil management measures to stabilize the Coon Valley watershed and promote the welfare of the community it supported.

The Coon Valley plan proposed to remove cows and crops from steep slopes and use the slopes for timber and wildlife. Gentle slopes were terraced or strip-cropped. Contour farming was practiced, along with crop rotation, and eroding gullies and streams were repaired and banks planted to soil-holding shrubs and trees. Intensive cropping of good land made up for land taken out of cultivation. A staff of young technicians planned the restoration of Coon Valley. Their task "was so large and so long as to stir the imagination of all but dullards."

The Coon Valley project has been a signal success. There were disappointments and mistakes, and even today some of the proposals, particularly those which might have doubled the area's game birds and other wildlife, have not been widely adopted. But the ugly scars of erosion, silt-covered bottomlands, and flash floods have been eliminated or greatly reduced. Facts learned by soil scientists and biologists at Coon Valley have helped save the soil of areas throughout the world. In 1955, a roadside marker was dedicated to honor Coon Valley's pioneers, and a plaque, erected to commemorate Wisconsin's pioneering soil conservation, bears these words:

> *"The outcome is a tribute to the wisdom, courage, and foresight of the farm families who adopted the modern methods of conservation farming illustrated here."*

The essential problem encountered by all of those who work to conserve the resources of the land, and which the Coon Valley experiment was designed to shed light upon, has been voiced by Noble Clark:

> "It would be relatively easy to control soil erosion if all of our land were in permanent grass and in forests. Under such conditions we could have the assurance that we were attaining really effective prevention of soil deterioration. But it would not be possible to support a growing American population on a land-use economy of grass and trees. The central problem in soil conservation is how we are going to obtain a reasonably effective control of erosion and at the same time make our farms produce the abundance of crops and livestock Americans must have if they are to maintain, let alone improve, their present levels of nutrition and well-being. Inevitably, soil conservationists must be willing to accept a degree of erosion control as being satisfactory which is substantially less complete than would be true if all the land were in grass or trees. . . Addition of lime, fertilizers, and legume seed to cleared sloping lands will increase forage production as much as tenfold. These findings make it all the more difficult for trees to compete with pasture in providing income; yet the evidence is convincing that keeping livestock off the steeper slopes, and having such areas in forest use, usually represents the most effective method of reducing water run-off, which constitutes a hazard to the fields below the steep slopes."

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"The current severe erosion now being accelerated in the corn belt under the influence of hybrid grains is another example of a faulty socio-economic farm philosophy, and is unrelated to the original prairie except insofar as the inherited soil richness—which hides the folly of the system—is the result of millenia of prairie activity."

—J. T. Curtis

Chapter Five

THE PRAIRIES

The primeval prairie was a vast sea of plants and grasses, so high in autumn they reached the waist of a man on horseback. The seeming endless expanses of the prairies awed many an early traveler, and to some they were frightening in their almost incredible monotony. Beneath the prairie vegetation lay a dark and rich soil, the accumulation of countless seasons of birth, death, and decay. The humus of the prairies was so thoroughly distributed and deep that it was difficult to say where humus ended and the substrata began.

Wisconsin lies at the northern edge of the Prairie Peninsula, so named because here the western prairies stretch far into the Midwestern forest region, through Illinois to Indiana and Ohio. In early days, the vegetation of most of southern Wisconsin was a mixture of oak-opening forest and of prairie, and in Rock, Grant, and Lafayette Counties, much of the land was open prairie. It was not, at first, apparent that crops would flourish on prairie soils. On the contrary, early migrants reasoned that these lands were sterile of plant nutrients because nothing but grasses and hardy prairie plants grew upon them. Moreover, the tough prairie sod resisted the best efforts to turn it, and the peoples who came to Wisconsin to build farms more profitably spent their time clearing forests. But with the advent of the steel plow, they quickly learned that prairie soil was the richest of all. By the time the wave of settlement had swept on to the open lands to the west, the prairie soils were those most prized.

Although the prairie sod was tough, the balance of nature had been built so delicately in the prairie lands that a single plowing was sufficient to destroy native vegetation communities forever. Only in the earliest records, or in some few small areas left untouched for one reason or another, can botanists now learn what the original prairie was like. Yet in these records, or in remaining prairie relics, may be found hints of methods by which man can perhaps rebuild a balance between plants and soil, thus restoring and replenishing some of the prairie's primeval richness.

There are certain advantages that prairie vegetation holds over cultivated plants, but they are not of the sort providing immediate economic returns. At the moment, it seems doubtful that there will ever be a call to re-establish areas of

An aerial view of part of the University of Wisconsin's Arboretum (foreground), with Lake Wingra in the center of the photograph and Lake Mendota in the distance. Part of the City of Madison lies between the lakes. . . In the foreground is the restored prairie used for research on prairie plants. Representative Wisconsin vegetation types established in the Arboretum—prairies, pineries, hardwood forests, marshes—are used for research on the State's native plants, soils, and wildlife.

prairie vegetation in the regions it once occupied—if, indeed, it could be accomplished with man's present knowledge. A. W. Schorger has pointed out that "all the knowledge of prairie ecology acquired during the past century is insufficient to enable man to restore it, should there be the will." The advantages of prairie vegetation, however, are such that it seems likely that some of the species—or some combinations of species—will ultimately become more useful as prairie soils become more depleted. Two researchers, W. C. Robocker and B. J. Miller, have pointed out that "various investigations over the past three decades have indicated that certain of the grasses native in the tall-grass prairies of the eastern Great Plains and the North-Central States are outstanding in the fields of erosion control and the restoration of the structure of cultivated soils."

The main advantages of these grasses are three-fold: First, the prairie flora builds —instead of breaking down—a rich, deep soil. Secondly, it has been shown by Wisconsin scientists, mature (technically termed *climax*) prairie plant communities are impaired little or not at all by repeated fires. In fact, fire may be a necessity to keep down shrub and tree invasion. Historical studies reveal that primeval prairie fires were a common occurrence—some were the result of deliberate firing by Indians to drive deer for hunting purposes.

Third, and finally, there is never a weed problem in areas of established prairie. Delicate though the balance of plants and soil may be in the prairie, the typical community of prairie plants is capable of withstanding any onslaught by weeds. The exceptional weed, possibly, is Kentucky bluegrass (actually introduced to this country from Europe) which can become established. But research at Wisconsin has shown that periodic burning will destroy bluegrass without harming prairie vegetation. Weeds will establish themselves on prairie that has been plowed, but if remnants of prairie vegetation exist and furnish a source of seed, prairie plants will eventually replace weeds, though very long periods of time may elapse before they do so. Wisconsin botanists are now working to learn how this last process might be accomplished more rapidly. Research on native plants and grasses has also pointed the way for pasture use of some lands that have hitherto been almost useless—particularly the dry, prairie hilltops known as goat prairies. Native prairie plants are so well adapted to harsh conditions that they can provide some forage during hot midsummer months when other plants are unproductive. Prairie vegetation on dry hillsides will withstand moderate grazing and often will improve under its influence.

Experimental communities of prairie plant associations have been established on two tracts in the University's Arboretum, one upon an area 60 acres in size, the other upon an area of about 40 acres. Initial attempts to rebuild the soil and vegetation of these tracts—which had been devoted to crops and hay for many years—were begun in 1935 on the basis of very little knowledge. By 1950 it was apparent that a useful experimental prairie community had been achieved, one that would be extremely valuable in plant, soil, and wildlife research.

In the reconstruction work, it was first necessary to learn the plant species present in the three general prairie types—wet, moist, and dry prairie—and the relative

Annual yields of prairie grasses on test plots are weighed . . .

percentages in which each species was to be found in each community. All known prairie remnants in Wisconsin were thoroughly surveyed, the plant species present and their relative percentages accurately counted and calculated. Lists were made of the rare species to be found, which are just as essential in their way. The plant species that were present in numbers exceeding 1,000 individuals per acre on remnant prairies were seeded into the Arboretum tracts first. Many of the rare species have yet to be introduced.

Wisconsin botanists have also studied how prairie plants are conditioned to prairie life, and they have found many unusual adaptations to extremes of heat and cold, downpour and drought, characteristic of prairie lands. Of 91 plant species studied, 73 per cent showed improved germination if seeds were kept at cold temperatures for a period of months before planting, and 39 per cent absolutely required this treatment. Many prairie species flower in spring. Traits of dormancy insure that they will not sprout and bloom until after they have been through exposure to winter's cold.

Knowledge of dormancy and delayed germination has also been obtained for a number of the prairie grass species. Native grasses of North America are exceptionally valuable. Of the crops grown in the United States, grasses probably have the most conservation uses, the greatest all-round value. They protect land from water and wind erosion. They improve soil quality, provide pasture and hay. Ever-greater areas in this country are continually being turned into grassland, and more and more different grass species are being used. Those that form sod are useful where rainfall washes away surface soil. Those that grow in bunches withstand grazing. Some grow fastest in spring, others in fall; together they provide summer-long pasture. Those that grow on upland are drought-resistant and are characterized by rapid growth of roots and tops to take advantage of a few moist weeks. None will germinate until a year has elapsed unless they have had special artificial treatment. In some, the greatest number of seeds germinate the second or third year, thus preserving the species through exceptionally dry springs and summers when seed production fails.

During the time in which the Arboretum experimental prairies were in the process of establishment, various weed control methods were tested in an effort to hasten the time when prairie plants could hold their own against weed competition. Cultivation, hand de-sodding, and burning were all tried. But none of these methods was as successful as a combination of burning followed by scarification of soil surfaces and then, finally, seeding of prairie species. Burning, conducted periodically, maintains the Arboretum prairie plant community, just as periodic pre-settlement fires maintained the vast, wild prairie lands. The burning suppresses growth of new shrubs and trees and improves the flowering of prairie species by removing grass mulch, in addition to destroying Kentucky bluegrass. Although the Arboretum's prairies are artificial and cultivated, not true replicas of the original prairie, they are among the most productive in the Midwest of information concerning some of our most valuable native plant

species. The information gained will be of tremendous value in maintaining the renewability of a valued resource, the prairie soil and its native plant communities.

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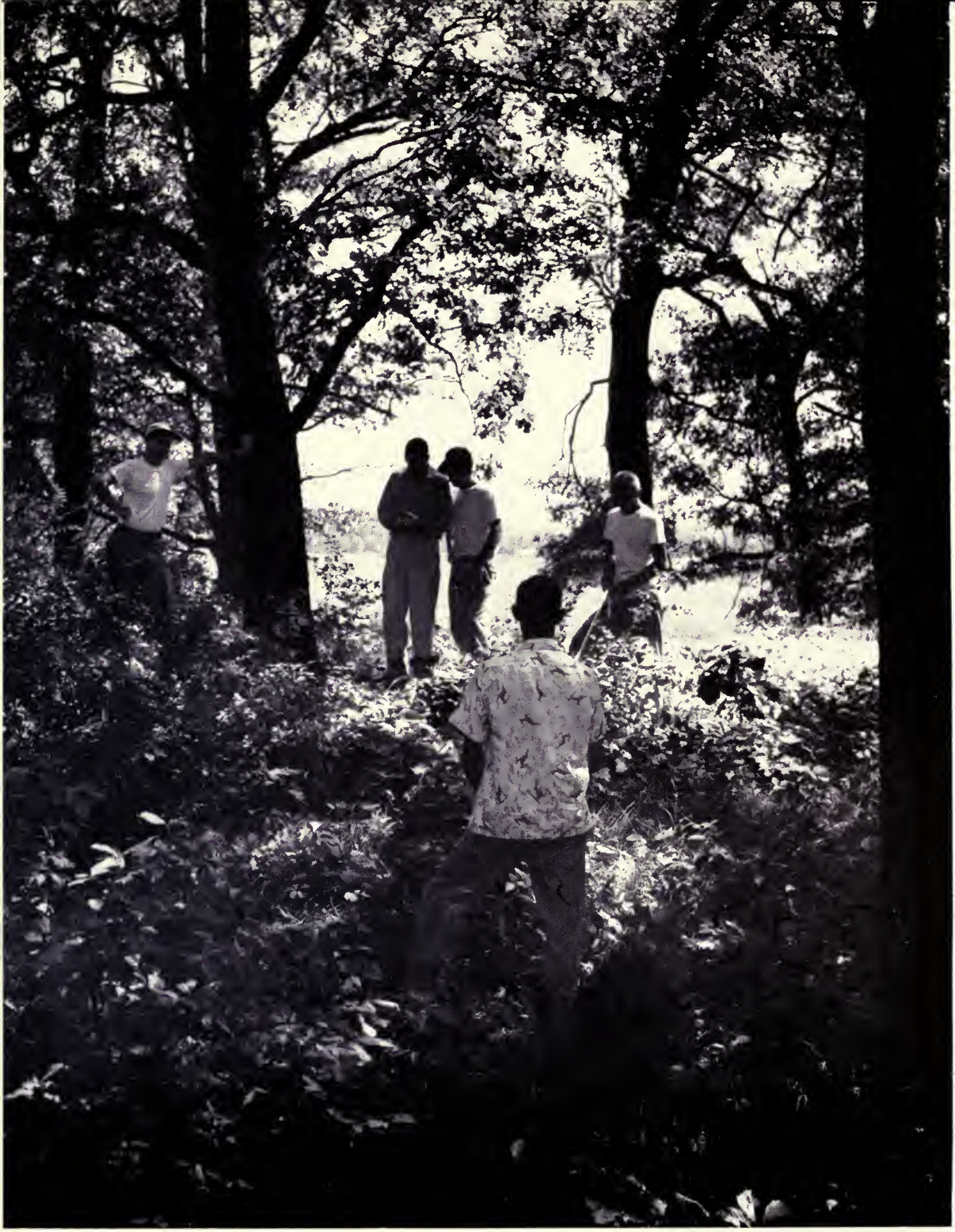

An ecology class studies the characteristics of a young oak opening forest in the University's Arboretum . . .

"It may be that our forests can be so handled that in the future the annual growth shall be equal to the annual consumption. In that case, forests may be perpetuated . . ."

—Charles R. Van Hise (1910)

Chapter Six

THE OAK FOREST

Some interesting things happened to the prairie lands of Wisconsin once the white man came. A large portion of the area in the southwestern counties was open prairie and what are known as oak-openings. It is estimated that, in general, these counties were some 20 per cent prairie and probably 60 per cent prairie in combination with oak-opening. The oak-openings were among the most picturesque of all the native North American vegetations, with widely-scattered, broad-crowned, gnarled bur oaks growing above a luxuriant blanket of prairie plants and grasses. Deer and other mammals, grouse and other birds of wide variety and abundant numbers were to be found along the streams, in the marshes, and around the occasional thicket.

Fortunately, we have an excellent record of what these lands were like. It lies in the dusty journals of the original government surveyors who carefully traversed the area between the years 1832–34 (the survey of the entire State was largely complete by 1860). To survey each township, initial boundaries were established by a traverse six miles on each side of the township. Then lines were run along the edges of the sections. At the end of each mile traveled, the surveyors entered into their notes such information as concerned the form of the land, the vegetation, the species of each witness tree, and the density of the species around it. Some surveyors kept better journals than others, but all the journals were recorded, and copies were made and filed both in the general land office in Washington, D.C. and the State land office. By going through these records, Wisconsin scientists have been able to map the vegetation existing in the State at the time of the original surveys. John T. Curtis outlined the original vegetation of the State by studying the survey records and published a map in 1948. Robert W. Finley had filled in many details by 1951, and several detail maps of smaller areas—including the Driftless Area, Dane, Dodge, and Rock Counties—have also been compiled.

Southern Wisconsin lies between two major regions, and in some ways is characteristic of both. Northward, the hardwood forests are native. To the south are the wide and open prairies. Southern Wisconsin, lying between them, has conditions favorable for the growth of both trees and prairie, and for this reason supported a mixture of both in pre-settlement times. There is considerable evidence that the parts of Wisconsin that were prairie when the white man came

had once been forest. It seems likely that throughout geologic history southern Wisconsin has been alternately forest and prairie, who knows through how many cycles of each.

There is also some meager evidence that in the early 1700s a vast fire swept through the entire north-central Great Lakes region—as far east as Pennsylvania—destroying many of the forests in the prairie-border region and restoring the land to prairie. That some areas never returned to forest (until the white man came) is laid to two reasons. Indians, knowing that animals flee in panic from flames, employed fire to drive deer into hunting traps. Lightning doubtless set an occasional conflagration. But of whatever origin, these fires spread uncontrolled before the winds, consuming broad expanses of prairie before they burned themselves out or were extinguished by rain.

Of all the shrubs and trees, only the tough-barked bur oaks can remain alive through these brief, scorching prairie fires, and a few survived to become ancient sentinels of the prairies and oak-openings. There is another interesting fact about prairie oaks. While the seedlings and saplings of other forest trees are killed by fire, life remains in the roots of oaks even though the tops be consumed repeatedly. Each year they send up new shoots. Autumn grass fires may destroy emergent foliage, but enough food is manufactured in a few green leaves to enable roots to continue growth. The famous naturalist, John Muir, believed that some oak roots—or grubs, as they are known—were more than a century old. Muir wrote: "Had there been no fires, these fine prairies, so marked a feature of the country, would have been covered by the heaviest forests."

Once the earliest white settlers had arrived, and fires had largely ceased, the prairie and oak-openings began to mature into oak forest. Within a hundred years, on areas where the plow had not turned prairie into farmland, mature forests became established. There are now 10 times as many trees on undisturbed areas as existed a century ago, and the total wood in the trees is eight times as great. The growth of forest from its early transitory stages into a stable, climax tree community (a process called *succession*) is not well understood. Until it is, forest management will proceed largely on a rule-of-thumb basis.

The study of succession is today one of the most promising ecological fields for those who would preserve the land and its vegetation as a renewable resource. Succession can be seen wherever the balance of nature has been destroyed by fire or other catastrophe. First, following catastrophe, annual herbs spring up; then come perennial plants and grasses, shrubs, and a century or more later, in forest regions, trees begin to dominate the landscape. Tree species then replace one another, and the climax forest (in most of northeastern United States) is finally achieved with some combination of sugar maple and beech or basswood. Where wind or fire destroy the existing climax, succession is apt to be rapid because even a hot fire does not completely destroy the organic matter of soil. If seed is present, climax species will often seed in directly. But succession also takes place on bare rock and at the margin of bogs and lakes. Mosses and lichens clinging to rock are building the first granules of soil that, in a hundred or a

thousand years, will support grasses. These, in turn, form sod to which the roots of shrubs can cling and which, finally, nourishes the gnarled roots of pioneer trees. The aquatic plants that surround lakes and marshes gradually fill in the shorelines. After many years, lakes shrink in area, become circular, then disappear entirely under a mat of bog plants and grasses, shrubs, and finally trees.

The hardwood forests of North America probably have been studied more intensively from a successional standpoint than any other forest type. The typical, native southern Wisconsin forest is composed of many tree species, but of these the black, white, and red oaks and the sugar maple are by far the most dominant. Black oaks are best fitted to gain a foothold on dry, open lands. Hence, they are the first to emerge from open prairie and primeval oak-openings (in which bur oak is most common). As the black oaks reach maturity, they create shade. Soil moisture accumulates. White and red oak seedlings grow in the shade, reach maturity, and eventually replace the pioneer black oaks. Finally, sugar maple and basswood replace the white and red oaks. The biology of succession was a mystery until relatively recently. Now it is understood, however, that seedlings of the pioneer tree species—of which bur and black oaks are examples—cannot tolerate shade. As seedlings, they thrive on direct sunlight and dry soils, not the moist soil and dim light of mature forest. But red oak and white oak seedlings *can* grow under these conditions, and eventually a black oak forest becomes a stand of white and red oaks. Seedlings of sugar maple are even better adapted to dark, moist conditions, and after perhaps a century, the sugar maples begin to thrust up into the sun, replacing the oak species that cannot reproduce in the darkness and humidity of the forest floor. All of these events take place gradually. There is never a time when the forest is a pure stand of one species or another, but the changes time works are eventually profound.

Modern ecological methods have been devised for precise study of the tree species existing in a forest and the proportions in which they are found, and from these tools can be derived knowledge of forest succession and, perhaps, eventually, of how it can be speeded or controlled. At each stage of succession in the forest community, there exists a specific association of fungi, bacteria, herbs, shrubs, insects, and animals. The balance of nature, so studied, is indeed a remarkable one and so consistent that in natural, undisturbed areas, the presence of certain species provides a basis for the accurate prediction that other species will also be found there. Thus, in a maple-basswood forest, for example, a specific association of bacteria, fungi, and lichens will be found in the soil, certain shrubs will be found growing beneath the trees, and even certain bird and other animal species will be found most often. In any large, natural forest, it is possible to find all stages of succession; natural disasters occur frequently enough to insure the perpetuation of species characteristic of each stage.

Just as tree species adapted for growth on one hillside may differ from those growing on the opposite slope, so do species that make up the forest of one region differ from those of another region. But differences from region to region are always gradual—there is no geographical point, for example, at which oaks

suddenly begin and conifers can no longer be found. The long gradation between one forest community and another is known as the *continuum,* so named by Wisconsin ecologist John T. Curtis. The eastern deciduous forest, extending from the seaboard to the prairie, is not a uniform one. Climax forests of much of the region are composed of two dominant species, sugar maple and beech, but as the northwest corner of the region is approached, beech is slowly replaced by basswood. The many individual forest types are all part of the continuum, and small differences from one mile to another become profound differences as miles are measured in hundreds. Knowledge of these differences will give man a better knowledge of how to utilize most efficiently the areas he devotes to forest by growing trees best suited to them.

Recent studies—and actual experience in woodlot management—have shown that farm forestry on ungrazed areas often can be economically profitable (see Chapter Four). What remains to be done to bring about greater utilization of Wisconsin's prairie and prairie-forest lands? Application of the biological principles governing succession will eventually increase the value of forest and woodlot resources. Much remains to be learned concerning the biological characteristics of southern Wisconsin vegetation, but the knowledge to be gained will assist in the restoration of productive forests on erodable hillsides and on lands unprofitable for crops. The Wisconsin Conservation Department, which administers the State's forestry program, has described the possibilities of forestry in southern Wisconsin in these words: "To the extent that circumstances warrant,

Instructor and student check the intensity of light in an oak opening . . . .

lands of southern, eastern and western counties not best suited for agriculture may well be devoted to the growing of trees. While this part of the State is primarily agricultural in character, there are millions of acres that could produce their best return through forestry." Concerning the long-range aspects of soil conservation in southern Wisconsin, John T. Curtis has pointed out:

> "In many of the older parts of the United States, woodlot destruction apparently proceeded even nearer to completion than has been the case to date in Wisconsin. This destruction was accompanied by excessive soil erosion, such that much land was rendered unfit for further cultivation. Following this, the farms were abandoned and have since grown up to forests again, commonly of lesser economic value than the original cover.
>
> "Must we in Wisconsin look forward to a repetition of this cycle—from forests to farms to eroded land and back to forests—or can we take the necessary steps to insure a permanent agriculture? The future prosperity of Wisconsin is dependent upon the latter choice. Specifically, we must remove the cows from the woodlots, place forests on the erodable hillsides, use contours and topography instead of quarter section lines for woodlot boundaries, and practice such other suitable conservation measures as will insure a continuously favorable balance between woodlot and cropland."

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". . . more and better future forests which can be operated intelligently under sustained yield management which will provide vegetation in the form of trees on our forests at all times. The time has definitely arrived for better forest management and selective cutting."

—George Kilp

Chapter Seven

THE NORTHERN FOREST

Wisconsin's forest wealth lies largely in the upland hardwood and conifer forests of the northern portion of the State. Very few remnants still exist of the great blanket of virgin forest the early explorers saw and so vividly described. But such remnants are of more than historical and scenic interest. Only in such mature—or climax—forests can scientific studies be undertaken to learn the methods by which northern tree species reproduce and how they replace one another in the march from pioneer stages to climax in which hardwoods predominate. Such studies, and the knowledge to be gained from them, are essential to the maintenance of forests composed largely of useful species. Important steps have been taken in the development of a science of forest ecology, but it must be said that the work has only begun.

Soil is the capital upon which trees draw for growth and life. In liquidating the problem of cut-over areas by planting conifers, soil suitable for hardwoods may also be liquidated. S. A. Wilde has pointed out that Wisconsin has thousands of acres of rapidly growing plantations that have already begun to yield pulpwood, employment, and taxes. But he adds:

> "These achievements in no way benefited the enormous acreage of the so-called 'hardwood lands.' Fine-textured upland soils which previously supported either hardwoods or hemlock and other conifers have a very high reproductive potential if they are utilized by suitable forest stands, but at present they support a melee of short-lived pioneers, non-merchantable species, and sprouts, usually supplemented by one group of faithful associates—parasitic and wood-destroying fungi."

In many respects, the process of succession is a soil-building one. Hardwoods and conifers tend, initially, to grow on different sites. Preferring fine-textured soil, upland hardwoods build a layer of humus that is amply supplied with nutrients in the form of the minerals classed as bases. Conifers are more closely confined to coarse and sandy soils of low fertility, and they tend to make soil acid. Conifers alone are qualified to grow—though even they will grow but slowly—in the peat soil of swamps and marsh borders. Planted to conifers, soil that is alkaline will become acidified, eventually to the extent that attempts to replace the conifers with hardwoods are likely to fail.

General rules, however, often do not apply to specific cases, and forest research at Wisconsin is aimed at obtaining specific knowledge of how to grow species

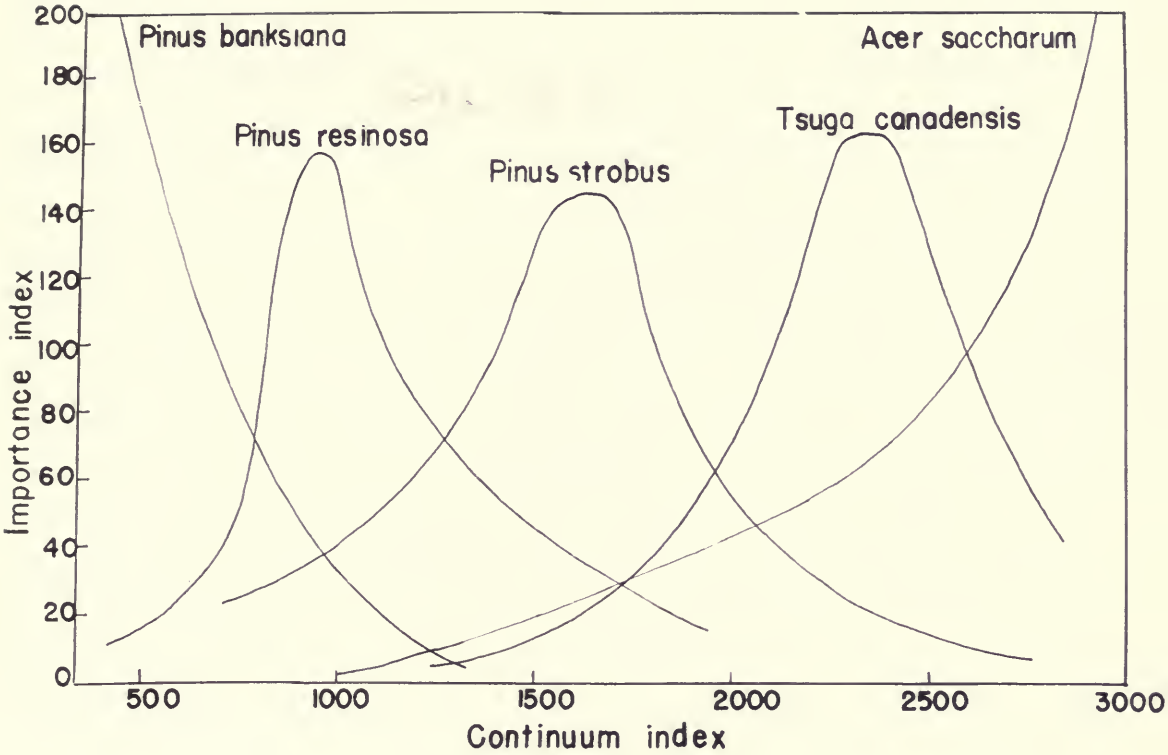
best qualified for an existence on every soil type. Wisconsin scientists have found that the assortment of species found in primitive, virgin forest is not necessarily a random one. Every species—and nearly every individual tree—exists and grows where it does for a definite reason. Were it not for the few remaining virgin forests, botanists would be hard put to learn the *hows* and *whys* of tree growth and the intricate inter-relationships existing between species. As early as 1907, botanists believed that "any plant stands where it does for the reason that the physical demands made by the structure and habit it happens to possess overlap in some degree the physical conditions prevailing at that place." Only within recent years, however, have the specific demands and conditions characteristic of each species been studied.

At the 1955 symposium sponsored by the Wenner-Gren Foundation, entitled "Man's Role in Changing the Face of the Earth," John T. Curtis pointed out:

> ". . . the climax deciduous forest is the ultimate in complexity, stability, and integration. Large numbers of species grow in intimate inter-relationship, with maximum capture and re-utilization of incident energy consistent with the seasonal nature of the climate. Many niches exist and each has its adapted species with the necessary modifications in nutrition, growth, and photosynthetic habit to enable it to make the most of its specialized opportunities. Not only is energy capture at a maximum in this highly organized community, but normal processes of peneplenization are reduced to a minimum. Indeed, there may be a decrease in randomness of the local habitat due to intake of highly dilute mineral elements from the subsoil or bedrock by tree roots and their subsequent accumulation in the humus-rich topsoil. . .
>
> "Man's actions in this community almost entirely result in a decrease in its organization and complexity and an increase in the local entropy of the system. Man, as judged by his record to date, seems bent on asserting the universal validity of the second law of thermodynamics, or abetting the running down of his portion of the universe. Perhaps the improbability of the climax biotic community was too great to be sustained and man is the agent of readjustment. Let us hope his new powers for total entropy increase are not employed before the readjustments can be made."

It will be many years before science has provided forest managers with the knowledge they need to attain most effective balances of tree species and soil for greatest economic efficiency, in addition to achieving optimum conditions for wildlife and outdoor recreation. A study of the upland-conifer hardwood forests in northern Wisconsin is part of a long-term University project to learn the characteristics of the major plant communities of the State and of the individual species that compose them. In a survey of 116 forests situated across the northern half of the State, Wisconsin botanists found that four species were of greatest importance in northern forests, but that no single species was ever important in a forest in which one of the other three was also present in sizeable proportions. Each of the four species is always found growing on sites providing characteristic soil and moisture conditions. At one end of the scale is jack pine—occupying sites of low moisture, low soil organic matter, and often acid reaction—and at the opposite end of the scale is sugar maple, found only where a rich soil has been built by previous generations of pioneer tree species. Ranged between the jack pine and sugar maple, were Norway pine and white pine, located at sites of increasing moisture and organic content.

In all the stands studied, jack pine was never found in any stand in which the major species was sugar maple, but hemlock and yellow birch were often



By conducting an extremely detailed study of the tree species in more than 100 separate northern forests, Wisconsin botanists have deciphered the behavior patterns of each tree species. In this graph is illustrated the fact that forests can be classified according to successional stage. Jack pine *(Pinus banksiana)* is most important in seeding barrens, then Norway pine *(Pinus resinosa)* may replace jack pine in the succession, followed by white pine *(Pinus strobus)* and possibly hemlock *(Tsuga canadensis)* until finally, after many generations and perhaps centuries of existence, the forest becomes a climax sugar maple *(Acer saccharum)* forest. Only natural disaster or clean-cutting will return a climax forest to some earlier successional stage (graph by R. T. Brown and J. T. Curtis).

abundant in the sugar maple forests. On the other hand, sugar maple was never found in a stand dominated by jack pine or scrub oak—the two species that are most often pioneers on unfavorable growing sites. These facts illustrate the ecologic law that each species has evolved to fill a specific niche in the environment. Some are suited for life and growth on land that has never before grown trees or that has been deforested. Others replace the pioneer species, and eventually, by substitution of one species for another, the forest reaches the climax stage. In northern Wisconsin, differences in geology and basic soil minerals are slight—there are no mountains or deserts or striking variations from the relative monotony of rolling hills, bogs, lakes, and streams. In such a region, slight differences in the physiology of tree species show up in striking fashion. Such conditions provide chances for unusually useful and enlightening research, but they also produce headaches for forest managers who must achieve growth of preferred tree species with what is still inadequate knowledge.

The early logging interests were not worried whether or not a continuing crop of valuable tree species would be available. In many respects, the early lumbering interests looked upon forests as miners look upon mineral deposits—"take out and get out." As economic demands increased, however, men became interested in gathering more than one crop of trees from the land, and a knowledge of the behavior of the various species—how they grow and how they behave when growing together—becomes of great value. Research will one day provide man with the knowledge he needs to achieve in his forests the kind of control he has achieved in his crops, and to do it on a continuing basis. It appears that the utilization of the natural forest community provides the greatest promise of making this possible. As it has been stated by a leading British ecologist, F. Fraser Darling:

> "A forest, we have learned, cannot be re-created merely by planting trees. We know a good deal more than we knew ten years ago, and governments are readier to support the research which needs even as yet to find how many organisms are involved in the circulatory system of a natural forest. It is clear enough that a healthy natural forest builds up natural wealth and does not dissipate it. One that has been disturbed and exploited may be losing capital. How? The answer which can show exactly the difference between these two energy cycles, the points at which there are slowings down of conversion, or bottlenecks caused by the chance extinction of a few plants or invertebrate animal organisms, is the stuff on which conservation policy in the future will depend."

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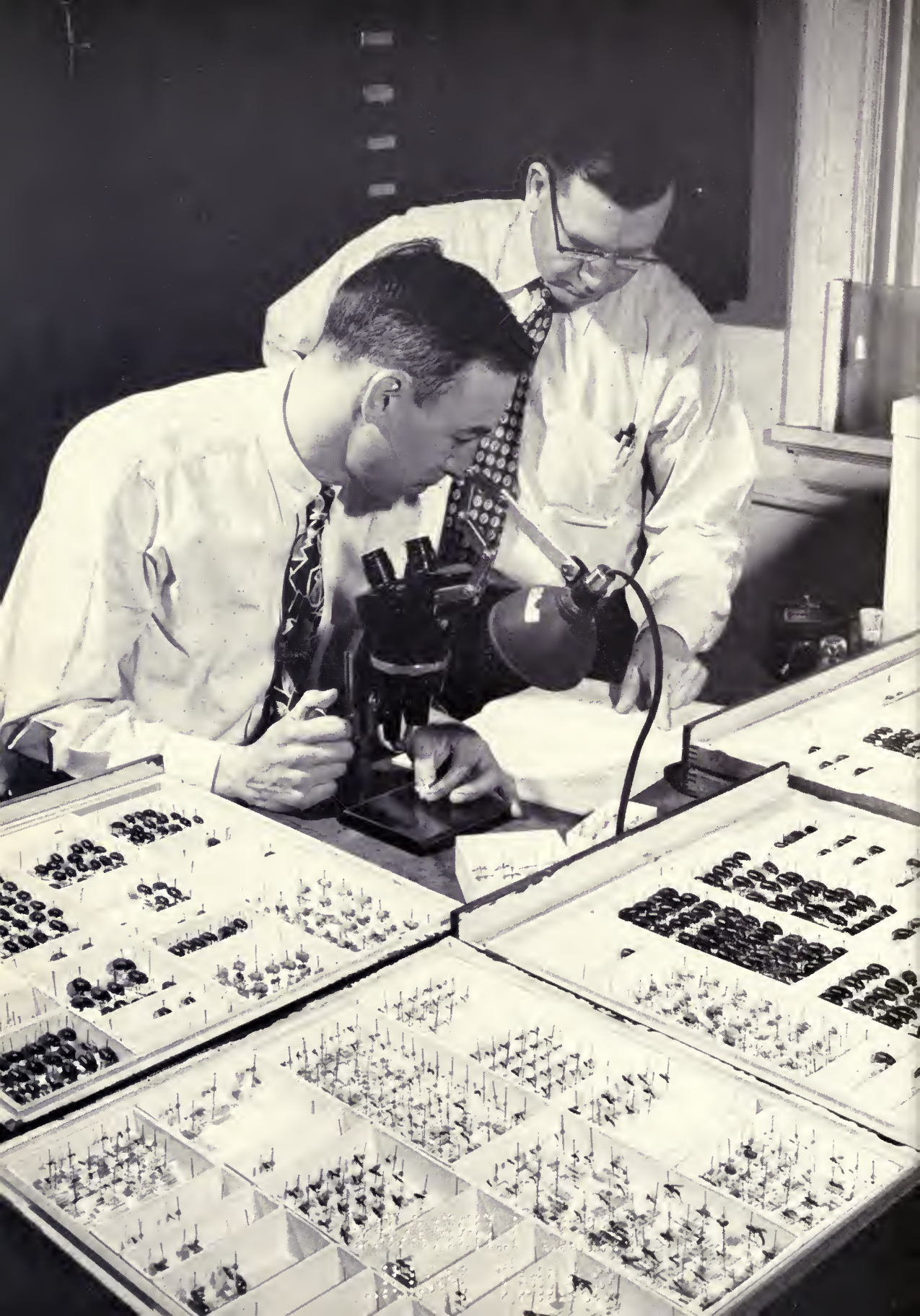
WITHDRAWN



"The fundamental influences of environment and heredity act on trees as on all other living things. . . In the forests, critical changes have come about because of cutting by the woodsman's saw, the sweep of fire, and killing both by insects and disease. Thus, conditions are quite different now from what they were for our virgin forests. . . Great possibilities appear for developing trees that not only are resistant to many of the important tree diseases, but also have other desirable characteristics."

—A. J. Riker

Chapter Eight

DISEASE AND INSECT THREATS

Infectious disease and injurious insects occur in all communities of living organisms, in forests as well as in the human populations of the world. Great epidemics and insect plagues must have swept through the forests of North America long before white man made record of the fact. It is true, however, that modern methods of transportation and tree cultivation often increase the likelihood of disease and of insect infestation.

Within the present century, chestnut blight destroyed all but a few chestnut trees throughout the entire eastern part of the United States. Great areas of what were once oak-chestnut forests are today oak forests. Fungus disease now threatens the elms in the eastern United States and the oaks throughout the East and Midwest. The oak wilt disease is now found in many areas of southern Wisconsin. It was discovered infecting oaks in six states in 1949, and by 1956 it was found in more than 18 states. It is the most serious forest threat to the oaks in these areas. Measures developed to prevent the spread of oak wilt are somewhat costly and difficult, but it appears that they may be effective.

The economic losses due to forest insects have been great in the forests of the Central and Lake States. In a single decade, 1910–1920, a billion board feet of tamarack, accounting for practically all the mature stands, were killed by the larch sawfly, but fortunately much of the economically useful wood was salvaged because tamarack deteriorates slowly. The spruce budworm killed some 75 per cent of the mature balsam fir in this area during 1913–26, amounting to some 20 million cords, of which very little was salvaged. Together, forest disease and insects outrank fire as a drain upon forest resources. Less conspicuous than fire, they are nevertheless continuously at work—and merit a research and control program as extensive as that now existing for fire control. With this fact in mind, the Wisconsin Conservation Department began to finance basic research on plant diseases at the University early in the 1940s. Initial funds, too, for research on insects were contributed by the Department in 1946, and for forest genetic studies in 1948.

A good portion of what is known about oak wilt disease was obtained by research at Wisconsin. Most important, perhaps, has been the discovery that the disease

is commonly transmitted through root grafts. The existence of root grafts was first discovered by J. E. Kuntz and A. J. Riker, Wisconsin plant pathologists. Roots of oaks growing closely together usually become intertwined, and many grow together, forming connections between vascular systems. Through such grafts, water and nutrients can move from one tree to another. Through these grafts, Wisconsin scientists found, the fungus of the oak wilt disease spreads from tree to tree.

This, of course, does not account for the fact that the oak wilt disease also spreads over great distances. Recently, researchers have found that the oak wilt fungus forms mats under the bark of infected oaks. Roy D. Shenefelt and Lester H. McMullen have confirmed the idea, long-suspected but difficult to prove, that sap-feeding insects are attracted to infected trees by the odor of the fungal mats. As they feed, these insects become smeared with the fungus spores. Then they may fly great distances, feed on uninfected trees, and rub off the spores of the wilt fungus on wounds.

At the present time, there exists no way of preventing the spread of the oak wilt disease over long distances. Methods have been developed, however, to prevent spread of the oak wilt fungus from an infected tree to the trees immediately adjacent to it. In natural forests, the disease spreads outward in concentric circles from an infected tree like waves from a pebble dropped in water. Wisconsin plant pathologists have shown that it is possible to sever root connections between oaks by trenching or with mechanical cutters devised for the purpose. It is possible, too, to create a buffer zone around an infected tree by poisoning its neighbors, thus preventing spread of the disease throughout an entire forest. For this, it is usually necessary to destroy trees in a 25–50 foot ring around a diseased tree to prevent spread of the disease through root grafts.

The insects thus far implicated in the transmission of oak wilt include certain sap and fungus feeders, bark beetles, and wood borers. Insect transmission of oak wilt is being studied as part of an ambitious program of entomological research which has been under way at Wisconsin for the past decade. Under the direction of University entomologists Roy D. Shenefelt and Daniel M. Benjamin, 28 separate projects have been proposed to obtain the information needed to control forest insects. A method has been devised to reduce insect losses in nurseries, and at present a general survey of Wisconsin's forest insects is being made. This survey will furnish the basis for an ecological study and, in turn, for the development of methods for improved insect control. Among the projects planned or now being conducted are studies of the larch sawfly, insects affecting pulpwood values, insect parasites, natural enemies of the pine sawfly, and the use of forest management practices in insect control. Forest entomology is a relatively new branch of the University's ecological research program. It will undoubtedly contribute importantly to practical forestry in the State. As Shenefelt and Benjamin point out:

> "Among the most valuable assets of the State of Wisconsin are its forests, farm woodlots, and plantations. Today, much of the lumber, paper pulp, posts, and poles used in the State comes from these sources. Untold wealth lies in the protection our forests

provide the watersheds of our industrially important rivers, soil from erosion, our fish and game, and the recreational and esthetic values of our vacation lands. Truly, great strength lies in our 15,000,000 acres of forest."

Insects and disease are an even greater threat in forest plantations than in natural forests. A native forest, with its mixture of trees of various species and different ages, possesses a good deal of innate protection from disease and insect damage. Insects and diseases are selective; a fungus that infects one tree species usually infects no other, and insects, too, are usually specific in their attacks. Natural forests, for this reason, are relatively free from danger of sweeping disease epidemics or insect plagues. Tree plantations, on the other hand, resemble cities—the close proximity of susceptible individuals makes rapid spread of either disease or insect pest a much simpler and more probable occurrence.

By selecting poplar trees of desirable types and resistant to disease, Wisconsin scientists have been able to breed new varieties that are extremely fast growing. These trees shown above have grown to seven inches in diameter and 50 feet tall in eight years. Some, in addition, possess striking advantages in terms of resistance to canker disease and to insect and rodent damage. The University of Wisconsin possesses one of the finest collections of poplars for breeding purposes in the world.

The disease that has, so far, given forest managers the greatest trouble in the northern forests and plantations is the white pine blister rust. The cause of this disease is a fungal parasite which requires alternate hosts for survival. The hosts needed are white pine, and, surprisingly, species of the *Ribes* genus, which includes gooseberry and currant bushes. The rust fungus will spread from white pine to *Ribes*, and from *Ribes* to white pine, but it will not spread from one white pine to another, although it will jump from *Ribes* to *Ribes*. For pines to become infected, *Ribes* bushes must exist in the vicinity of pine forests or plantations. This simplifies control of the disease. Once the *Ribes* bushes have been eliminated, no further danger from blister rust exists.

White pine in southern Wisconsin has never been seriously threatened by the blister rust. Why this should be true was a puzzle for many years. The answer came in 1953 when University researchers found that rust spores from *Ribes* could infect pines only after a prolonged period of foggy, cool weather. Whenever the weather in southern Wisconsin was warm and dry, there was negligible danger from the rust fungus, the scientists found. Southern Wisconsin rarely furnishes the conditions needed for large-scale epidemics of the rust disease—while northern Wisconsin often does.

Wisconsin has about a million acres devoted to white pine forest. Half of these acres are growing white pine stands sufficiently valuable to merit protection from the disease. Control of blister rust very likely saved the State some $40,000,000 in white pine lumber. In a continuing program, University scientists have searched widely for resistant pines, and plant pathologists have selected and propagated some three dozen trees that have demonstrated resistance to rust infection for more than 15 years. Progeny of these trees will be introduced eventually for use on those areas in the State where the terrain is too rough for *Ribes* control measures or where too many bushes exist for effective eradication.

In Wisconsin's forests, insect infestation and disease are among the unforseen consequences of the logging ventures of the past century. It seemed logical to the early lumbering interests that new forests would quickly replace the logged ones, but it was soon apparent that this was not to be the case. At first, repeated fires kept new forests from growing. Once effective fire control measures were instituted, it was learned that planted forests, like planted crops, are notably subject to disease and insect threats. As man plants more trees, the danger of widespread loss becomes even greater. Research programs have become a necessity to meet the continual threat of plague and epidemic.

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"Yes, Wisconsin has made advancement. One of its fundamental achievements has been land zoning in the former cut-over areas. This philosophy recognizes not only the limited uses to which land may be put, but it definitely recognizes use for all land. From this idea came an orderly development of forestry, commercial recreation, and agriculture in the north country."

—Ernest Swift

Chapter Nine

RURAL ZONING

It required an economic depression to induce Wisconsin to make large-scale practical use of the knowledge of soil, climate, and vegetation gained during the previous century.

Just as the work conducted in Coon Valley was inspired initially by economics—with the Dust Bowl providing a grim example of soil exploited beyond endurance—so the institution of rural zoning in northern Wisconsin was largely the result of economic pressure. With dwindling county revenues during the 1930s, it was manifestly impossible to maintain roads and schools in all of the districts of these counties. The designation of some areas as "out-of-bounds" for agricultural settlement was a pioneering experiment in social planning based on a scientific knowledge of renewable natural resources.

The economic problems of the 1930s made it evident that large areas of land in northern Wisconsin were not suited for supporting farm families, particularly those located far from trade centers and schools. Transportation costs were greater than the income the northern farms were capable of providing. It was both economically and socially advisable that farming be restricted to areas suited to farming. There were also advantages to be gained in terms of the transportation of farm produce and in terms of better educational and social opportunities.

County government in Wisconsin, thus, became the chief agent of land conservation in many areas of the State, not by design but by necessity. Zoning ordinances were built on a legal framework erected a decade earlier and on the general acceptance of the value of conservation practices. In 1923, the Wisconsin Legislature had passed a law that gave county boards the authority to handle certain problems of urban counties. In 1929, zoning regulations for rural areas were written into this earlier piece of legislation, and closely thereafter came the forest crop laws and the county forest reserve law. The Wisconsin Attorney General's office, in reply to a series of questions by the legislative committee studying rural zoning, wrote: "The county zoning ordinance is undoubtedly in the public interest. The cut-over areas of northern Wisconsin speak as eloquently against haphazard development as any city condition."

Forests now support a large proportion of county government costs . . .

The Wisconsin rural zoning program is the product of the efforts of many individuals and, in a real sense, the conceptions of land economics that lay behind rural zoning were the result of stark desperation and not economic theory. The rural zoning notion, once established as a possibility, was soon adopted by State leaders and public-spirited men and women in the northern counties. The first request for a rural zoning plan came to Chris L. Christensen, dean of the University's College of Agriculture. University faculty members who helped in rural zoning were, among many others, Walter A. Rowlands, now director of the University's Branch Experiment Stations; Frederick B. Trenk of the University's forestry staff; and L. G. Sorden of the University's Agricultural Extension Service. Frederick G. Wilson of the Wisconsin Conservation Department played a major role in rural zoning planning and administration. But to be complete, the list would be a long one, and would include county and industrial leaders throughout the State.

The first county forest was established in 1930. A year prior to the first zoning act, Benjamin H. Hibbard had said: "Whether we like it or not, a new public domain is appearing in Wisconsin and other states as a result of tax delinquency." Little more than a decade later, University agricultural economists George S. Wehrwein and Raleigh Barlowe wrote of the Marinette County forest program: "In this county, future forest receipts may go a long way toward paying the costs of county government." The opinions of those who held even more optimistic views were justified. John Saemann, Marinette County forestry agent, reported in 1955 that county income from forestry for that year was expected to reach $100,000, providing a large percentage of the county's annual budget.

Rural zoning was as sound from a scientific standpoint as it was from an economic and social one. If it had not been, it is doubtful if so unprecedented a program could have been established so quickly, or once established, could have survived the test of time. Rural zoning today, some two decades after it was begun, has become an established part of government in Wisconsin's northern counties (and in 17 counties in the central and southern parts of the State) and has been widely adopted by all of the other states in the western Great Lakes region. The basis of rural zoning can be summarized easily. It is simply that soil in many areas is incapable of supporting profitable agriculture under present economic conditions. Trees and wildlife, on the other hand, do well on these lands. Recreation and summer residence are other uses.

In Wisconsin, the amount of pulp wood being grown annually is catching up with annual consumption and the time can be foreseen when the State's paper mills will no longer need to import from Canada and elsewhere the raw material needed to operate their plants at full capacity. Moreover, Wisconsin's potential for producing recreational facilities is almost without limit; recreation is a land utilization that extracts nothing from soil or other resources.

It is true that rural zoning and forest crop laws were written with forestry in mind, and not wildlife, but game and other wildlife species have incidentally

. . . on what was once a land of shattered hopes. Northern counties are being returned to their rightful heritage, trees and wildlife, for which they were by nature intended.

benefited and management measures to improve conditions for game have been instituted at an increasing rate. It is to be hoped that this awareness of the value of Wisconsin's wild resources will become more widely accepted, and that management measures as advanced in this field as those employed in forestry will be practiced on these lands.

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PART II

"An important characteristic of science is its incapacity to be impractical. The most far-reaching discoveries and the most widespread useful applications regularly flow out of ideas which initially seem abstract . . ."

—Warren Weaver

A wildlife crossroads . . .

"If books are to consist of more than collections of mere words, they must be based on knowledge such as can be derived only from research. One of the most powerful factors limiting development of some of the so-called backward countries has been their dependence on a literature developed in other and dissimilar parts of the world."

—WILLIAM VOGT

Chapter Ten

WILDERNESS AGAIN

THE EARLY EXPLORERS TOOK LITTLE NOTE OF PLANT SPECIES AND MENTIONED ONLY one or two in their journals, but the birds and animals found in the new land were of great interest, partly because man has been ever fascinated by wild creatures, and partly, also, because he finds them a source of food. In his monumental histories of wildlife species native to Wisconsin, A. W. Schorger has provided scientists with a storehouse of knowledge regarding original ranges and abundance of birds and other game animals. Schorger's scientific papers on the bison, elk, quail, ruffed grouse, the prairie chicken and sharptailed grouse, deer, turkey, bear, and squirrels, and his book, *The Passenger Pigeon*, represent more than two decades of spare-time searching through old journals, histories, and original newspaper files for information, in addition to correspondence and interviews with persons who saw these birds and mammals in their original abundance.

From these records, scientists can discern the reasons why some of these species survived while others were extirpated. Often, knowledge can be obtained which is of value in efforts to insure continued abundance of the species that remain. A professional chemist and an industrialist, Schorger has become one of the world's recognized authorities on the history of the species of wildlife found in the Great Lakes region. He retired from the presidency of a chemical firm in 1951 and became a member of the University faculty. He was appointed a member of the Wisconsin Conservation Commission in 1953.

The earliest record of wildlife in the State is found in the writings of Radisson, who killed "staggs" in northwestern Wisconsin in 1661–62. Allouez mentions that "large and small staggs" were to be found at the mouth of the Wolf River. The "staggs" and "large staggs" were elk, and the "small staggs" were whitetailed deer. Jonathan Carver, writing of a trip up the Chippewa River in 1767, said that the largest droves of elk and buffalo he had ever seen filled the meadows along the banks of the river. There is no known record of elk in southeastern Wisconsin after 1828, and the animal evidently also disappeared in the southwest counties by 1850. In northern Wisconsin, elk were to be found for some years after that, but size and the relative ease with which the animal could be hunted down resulted here, too, in extirpation.

One of the first writers to mention the ruffed grouse was Baron La Hontan, who was served "woodhens," as he termed them, at a feast held in 1688 in Green Bay. The ruffed grouse was not often mentioned, however, because it was difficult to hunt, and in the early days was obtained more or less accidentally by hunters in pursuit of other game. The first description of prairie chicken was given by Marquette, who records that a "partridge" was shot and that it possessed feather tufts and bare spots on its neck, indicating that it was a male prairie chicken. This incident, however, took place south of what is now the border between Illinois and Wisconsin, and historical record of prairie chickens in Wisconsin does not occur until 1831 when Henry R. Schoolcraft, the first man trained in natural science to travel through Wisconsin, reported that he was "often startled by the flocks of the prairie-hen rising in the path."

Schoolcraft was official geologist on an expedition that left Detroit in 1820 to search for the source of the Mississippi River. He was the first to make anything resembling detailed notes of Wisconsin birds, recording vast numbers of "wild pigeons, prairie-hens, ducks, and plover." Schoolcraft was later appointed an Indian agent, and was stationed at Sault Ste. Marie from 1822 until 1841. On April 23, 1823, an Indian boy brought him a "grosbec" that proved to be new to science, a bird species we know as the evening grosbeak. In 1831, Schoolcraft descended the Namekagon River, and in records of this trip, mentions flocks of prairie-hens. He also wrote that "ducks and pigeons appear common." The following year, Schoolcraft was a member of the party that discovered Lake Itasca in Minnesota, but after that year his writings were exclusively on the subject of the Indian tribes of the Great Lakes region.

Others were soon to take up the study of Wisconsin's birds and animals. They were often the same individuals who conducted initial surveys of the plant species native to the State. In 1852, Increase A. Lapham published his first lists of species, noting that "they are very far from being complete lists of our fauna and flora, only such species having been included as have been actually observed by me, or were communicated to me by competent persons. . . They embrace 62 mammals, 287 birds, 19 reptiles, 14 fishes, 90 mollusks. . ."

Lapham aroused an interest in natural history in Dr. Philo R. Hoy, an Ohio medical school graduate who came to Racine to practice in 1846. In the next quarter century, Hoy observed 318 species of birds, 1,300 beetles, 2,000 moths, and many mammal and reptile species found near Racine. He was also one of the first to study the fish, plants, and invertebrates found in the deeper waters of Lake Michigan. Just as Judge Knapp had remarked on the influence of Wisconsin's climate on the trees and other native plant species, so Hoy noted that in Wisconsin "the isothermal line curves farther north in summer and retires farther south in winter than it does east of the Great Lakes; which physical conditions will sufficiently explain the peculiarities of its animal life, the overlapping, as it were, of two distinct fauna." Among the southern birds Hoy noted in Wisconsin in summer were the yellow-breasted chat, mocking bird, Carolina parrot, wood ibis, and royal tern. Arctic birds which he noted visiting Wisconsin in

winter included the great grey owl, the hawk owl, Arctic three-toed woodpecker, Canada jay, evening grosbeak, King eider, black-throated diver, and the glaucus gull.

The result, said Hoy, was that within the "narrow bounds of Racine County there have been collected over 300 species of birds; more than have as yet been noticed in any single state—nearly one-half of all birds known to the naturalists within the entire territory belonging to the United States." In 1885, however, Hoy recorded that man's influence had resulted in the marked decline or disappearance of many species including quail, ruffed grouse, prairie chickens and sharptails, sandhill cranes, woodcock, and some 20 additional species.

The name Franklin H. King, one of the most important in the early history of soil research in Wisconsin, is also one of the most prominent in early wildlife research. King was the first to employ what is today called the transect count. As early as 1877, he published lists of birds found on different vegetation types—a technique that many ecologists now consider a new one. King also studied the food habits of 295 Wisconsin bird species, recording the stomach contents of 1,608 individual birds, to learn whether these birds were beneficial or detrimental to man's interests. He noted that most species were economically harmless or decidedly beneficial, and saw that many bird species adapted readily to man:

> "Two hundred years have been sufficient to produce such marked changes in the habits of many American birds as to have caused them to assume entirely new relations to human interests. . . Many, like the swallows, now build their nests in situations whose surroundings are so entirely different from those of their original haunts that the character of their food must have undergone as marked a change as have the situations in which they build their nests."

But perhaps the greatest of the early Wisconsin naturalists was Thure Kumlien, whose knowledge of the native plants and animals was certainly as extensive as any. Had it not been for Kumlien's reluctance to keep notes and publish his findings, he would rank with the outstanding naturalists of his day.

A native of Sweden, Kumlien left Upsala University during his senior year and made arrangements to come to this country when he failed to obtain parental consent to marry below his social status. He had already conducted some work in natural history for the Swedish government, collecting plants and birds in the Baltic Islands. This experience must have convinced him he could make a living collecting specimens in Wisconsin, selling them to museums and private collectors.

Kumlien arrived at Milwaukee in 1843 and walked 60 miles to Lake Koshkonong to select land. He built a log cabin and made some effort to farm, but he was to attempt what was at that time an unheard of venture, and he was to succeed to a limited extent. Although collecting and selling specimens was slow in producing income, Kumlien eventually developed a profitable arrangement with eastern naturalists who helped supply the growing demand for museum specimens in this country and abroad. Because he sold many specimens to foreign

museums, Kumlien was at one time better known abroad than he was in this country. It was written of him: "No state in the union has ever had so complete a master of its whole flora as Wisconsin had in this extraordinary man, whom our eastern botanists seldom heard anything of. . ." It was also said Kumlien's "records have given us a better picture of the bird life of early Wisconsin than those of any of the other pioneer naturalists. Had he had more time for his favorite pursuit, and the will to publish, our knowledge of the ornithology of his period would have been enriched far more."

A son was born to the Kumliens at Lake Koshkonong in 1853. Aaron Ludwig Kumlien was also to achieve distinction in the field of natural history, and it is perhaps his name, along with that of Ned Hollister, that is best known today among Wisconsin ornithologists. A book entitled *The Birds of Wisconsin* was first published by Kumlien and Hollister in 1903 and has recently been reprinted by the Wisconsin Society for Ornithology. It is the principal reference work for Wisconsin's 357 species and subspecies of birds. Aaron Kumlien was a student at the University for two years, 1875–77, and was then appointed naturalist to the Hougate Polar Expedition, 1877–78. Upon his return, the expedition collections were given to the Smithsonian Institution, as had been the agreement, and Kumlien embarked upon a quiet but influential academic life as scientist and teacher in Wisconsin.

The applied science of wildlife management was born in the 1930s. There are few who would dispute that its birthplace was Wisconsin, or that its name is linked inseparably with that of Aldo Leopold. But at this point another name not often connected with ecology or conservation must be mentioned. It is that of Harry L. Russell, a bacteriologist who became dean of the University of Wisconsin College of Agriculture, and who was appointed director of the Wisconsin Alumni Research Foundation in 1931. Russell was the son of a country doctor in the village of Poynette. His interest in the abundant plants and animals of the Wisconsin countryside was aroused early and some of the plants that he collected in that area are still preserved in the University's herbarium. Although Russell's fame rests largely upon his contributions to the science of bacteriology, the strength of the University's conservation program in no small measure must be attributed to him. In the late 1920s, he saw the need for a professorship in the field of wildlife management. In 1933, when he was director of the Foundation, Russell was influential in establishing such a professorship at the University, supported by funds provided by the Foundation. Aldo Leopold was appointed to the post.

A forester by his early training at Yale's School of Forestry, Leopold had a consuming interest in animal and bird life, and it led him to study the wilderness, not as made up of parts but as an interwoven whole. He forged ideals that now guide the conservation movement throughout the world.

Leopold began his professional career in New Mexico and after 15 years became chief of operations for the U.S. Forest Service in the Southwest, a position he

The late Aldo Leopold, founder of the applied science of wildlife management, and professor at the University of Wisconsin, 1933–48.

left in 1925 to come to the U.S. Forest Products Laboratory at Madison as associate director. Leopold's studies of game birds and animals and of wildlife management, a sideline for him until then, became a profession in 1929 when he was appointed by the Sporting Arms and Ammunition Manufacturers' Institute to conduct a survey of wildlife resources in the central Midwest states, a pioneer study of its kind. The survey was complete by 1931, and Leopold turned to the writing of his classic *Game Management,* which was published in 1933. The basic science of ecology and its applied counterpart, wildlife managment, found in Aldo Leopold a philosopher whose visions were rooted in fact and whose ability to communicate those visions has been without equal. His philosophy is outlined to some extent in his first book, but what has come to be called the *conservation ethic* finds more adequate expression in *A Sand County Almanac.* Leopold's most enduring contribution probably rests in the ideals he forged for resource management. He could see that, for one thing, wilderness had a role to play in American culture, and it was his personal conviction that wilderness has an often unrecognized influence on the health and growth of individuals. Leopold felt strongly that everyone needs an occasional brush with wilderness to recall the essential fact that Man is part of Nature. Leopold knew science could prove that wilderness areas are needed for research purposes; he also knew that man needs wilderness at times to refurbish the essentially human qualities. Leopold held the conviction that the world would be a poor place without wildernesses: "Of what avail are forty freedoms without a blank spot on the map?"

Regarding the practical questions of conservation, questions involving resources which man taps daily for his livelihood, Leopold saw that many conservation practices were followed because they were traditional, and that many of the accepted ways of doing things were not as good as men thought they were. Many of these practices were—and still are—not the sole agents for the benefits attributed to them. He wrote:

> "In general, the trend of evidence indicates that in land, just as in the human body, the symptoms may lie in one organ and the cause in another. . . The practices we now call conservation are, to a large extent, local alleviations of biotic pain. They are necessary, but they must not be confused with cures. The art of land-doctoring is being practiced with vigor, but the science of land-health is a job for the future.
>
> "A science of land-health needs, first of all, a base-datum of normality, a picture of how healthy land maintains itself as an organism. Paleontology offers abundant evidence that wilderness maintained itself for immensely long periods; that its component species were rarely lost, neither did they get out of hand; that weather and water built soil as fast or faster than it was carried away. Wilderness, then, assumes unexpected importance as a land-laboratory.
>
> "One cannot study the physiology of Montana in the Amazon; each biotic province needs its own wilderness for comparative studies of used and unused land. It is of course too late to salvage more than a lop-sided system of wilderness remnants, and most of these remnants are far too small to retain their normality. . . All wilderness areas, no matter how small or imperfect, have a large value to land-science. The important thing is to realize that recreation is not their only or even their principal utility. In fact, the boundary between recreation and science, like the boundaries between park and forest, animal and plant, tame and wild, exists only in the imperfections of the human mind."

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"There is a fascination in the study of wildlife populations when inquiry is directed to final causes."

—A. W. Schorger

Chapter Eleven

ROAD TO EXTINCTION

The fate of the elk, bison, and turkey, all of which were present in great numbers when Wisconsin was first traversed by white men, provides our most vivid example of what happens when food and cover are changed and destroyed.

These species were extirpated quickly once the white man came to stay. Hunting was the cause of initial declines from former abundance, but changes in the land would have made continued survival for these species, even in reduced numbers, impossible. The elk and buffalo are unwary animals that can be hunted down with ease. Hunting decimated the turkey, and by the time protective laws were written, the State's oak openings had been destroyed or had grown into oak forest, no longer affording suitable turkey habitat. In the case of the passenger pigeon, too, hunting was probably the cause of extinction. Pigeons were shot by hundreds of thousands as they gathered at nesting sites. In the year 1871, sixteen tons of shot were sold, largely to market hunters, in the city of Sparta alone. The pigeon's slow rate of reproduction rendered this species incapable of recouping such heavy losses. Of these four—elk, bison, turkey, and passenger pigeon—only the pigeon could possibly have continued to survive under the conditions white man created once he had settled in Wisconsin.

Other species, such as the sharptailed grouse, extended their range northeast from Wisconsin and into the Upper Peninsula of Michigan, following in the wake of logging and the slash fires that turned the land into barrens. Quail and prairie chicken apparently became more abundant in southern Wisconsin under the early types of agriculture, and they were then pushed into central Wisconsin when farming became more intensive and crop rotation practices characteristic of dairy agriculture came into general use.

Deer, once most abundant in southern Wisconsin, moved north before the plow into areas of young forest that grew in the wake of the logger, and they were soon to be found on the shore of Lake Superior, where they had rarely been seen before. The whitetail is now moving north into Canada, and the moose is backing into the northern tundra. The cottontail follows northward in the track of the snowshoe hare, and the jackrabbit has come in from the southwest in the footsteps of the cottontail. The jackrabbit is an indicator species; it points the direction the land is moving—from meadow to dry, sparse brushland, the indelible mark of over-grazing, over-cropping, drainage, and drought.

A major aim of research on Wisconsin's wildlife is to learn ways of providing conditions for survival of wild bird and mammal species in the State. It has

Wildlife food and cover in a corner of the farm—plus a farm woodlot; good conservation practice for agricultural areas.

become obvious that for native species, native vegetation is essential. For species such as the pheasant and Hungarian partridge, neither of which is native to the State or even to this continent, agriculture provided the base upon which populations became established. Sometimes very simple measures result in marked increases in game bird and animal species. One of the tasks of research is to find out what these measures might be, and what they might accomplish.

Many areas of Wisconsin have been restored to forest and, incidentally, to wildlife. Many drained lowlands that have outlived their usefulness (or which were never useful) have been restored to marshland for waterfowl and water storage. Many more could profitably be so restored. For the portion of Wisconsin now in productive agriculture—the largest percentage of land area in many parts of the State—the best method of providing habitat for native species is through maintenance of small food and cover areas for wildlife and in the preservation of an occasional farm woodlot. Fencerows are of value for shelter and for the travel lanes they establish between cover and feeding areas. Although there is no doubt that shelter—or, technically, cover—is essential for upland game birds and for all game birds and animals, research has yet to reveal the plant species and the combinations of cover types that are most effective. For this reason, selection of plant species for artificial planting of game coverts is still a matter of rule-of-thumb. Plants are the basis of life for game birds and animals. Plants that provide food and cover most abundantly would be of greatest value in game management programs. A knowledge of where each species grows best and what combinations of species are most effective would be of great value in the work of improving conditions for wildlife. As S. A. Wilde writes:

> "The mere occurrence of a species on a certain site is not necessarily proof of its ability to produce an abundant food crop. Many game food trees and shrubs in Wisconsin do not always have satisfactory production of seeds and fruits. Their restricted bearing appears due to the low soil fertility as well as to deficiencies in light and to climatic extremes. . . Wisconsin has large areas of soils in a critical state of fertility as far as some game food plants are concerned, especially on burned-over podzols and coarse siliceous sands in which the destroyed organic matter had been the principal source of plant nutrients.
>
> "Hazel, one of the least exacting and widely distributed shrubs, is an example. In the autumn of 1944 there was an exceptionally abundant crop of hazel nuts in Wisconsin, but bushes on severely burned podzol areas in the North remained conspicuously barren. Bearberries, which are widely distributed on sandy outwash in central Wisconsin, provide another striking example of meager fruit production on depleted soils. Observations by Leopold on red raspberry, sand cherry, and hazel growing on the poor sands of his farm in Sauk County, Wisconsin, show only vegetative propagation; there has been no fruit during the last 10 years. The hazel and raspberry fruit regularly, however, on better soils of the same farm."

Wilde studied the soils and sites where common game food plants were found. He selected seven plant species for the work; these in particular because they grow wild in the State, can be propagated in nurseries, and have direct value as game food and cover. Wilde found that the seven species could be arranged along a scale, according to the soil type preferred: mountain ash on the most acid soil, red cedar, wild crabapple, and highbush cranberry on the most alkaline. Ranged between were hawthorne, black cherry, and red-osier dogwood. While

this study is informative, it was by no means intended to be more than a demonstration. Additional studies, eventually covering all of the plant species of value to wild game in the State, would provide useful information for achieving better stands of food and cover plants on game lands.

Herbicide sprays will be of value in maintaining food and cover patches. As K. C. Hamilton and K. P. Buchholtz have shown, plots of relatively useless vegetation—nettles or grass—can often be converted to more useful plant associations at low cost. Expanses of grass sod can be destroyed and nutrients released to

A. W. Schorger, member of the Wisconsin Conservation Commission and professor at the University, whose histories of wildlife in early Wisconsin describe early abundance and provide clues to methods by which that abundance can be maintained for many of the State's remaining game species.

support herbaceous vegetation of greater value to wildlife. Corn, a staple food for pheasants and quail, can be grown without plowing or cultivation; weeds can be controlled in early summer when they compete with corn, then permitted to grow in late summer to provide cover between corn rows. Sprays, it is hoped, can be used to break up expanses of *Phragmites* in marshes, thus enlarging areas usable by waterfowl. It seems possible that "weed" trees could be sprayed from the air, destroying tops and encouraging sprout growth, providing additional browse for deer. Methods have yet to be developed by which grasslands can be sprayed to encourage growth of native, game-food shrubs, but methods already available should make it possible to convert shrubby areas back to grassland for prairie grouse.

While herbicides have increased the tools available for game management, many are still expensive and much research remains to be done before we know whether vegetation suited to game and wildlife could be maintained by spraying alone. We do not yet possess techniques to fully control the vegetation of either forests or game management areas, but some major steps have been taken in the job of developing them.

Knowledge of plants alone, however, is not sufficient for game management purposes. Wildlife scientists must also know the feeding patterns of game birds and animals. They must know which plant species will be utilized for food by the various game species, which ones are sufficiently nutritious to carry game through winter, which are of most value as both food and cover. These inquiries are termed food-habit studies and such studies have been conducted—or are now under way—for most Wisconsin game species. Paul L. Errington has written:

> "It is fairly easy to classify winter foods for game into two extreme groups, namely, those which are of known excellence as staples and those which are so inferior that they are hardly eaten, even when prominently available. Intermediate between the obviously good and the evidently poor food types we have a third group, the constituent items of which are not so easy to place on the nutritive scale. Conservationists and game managers could well learn more about this third group, since its constituent foods frequently play an important part in the lives of such gallinaceous game as ringnecked pheasants and bobwhites during the periods of winter food crisis."

Knowledge both of the most useful plant species and of where they grow best is essential to planning game management areas. At the present time, little information exists on the merits of various types of mixed food and cover plantings. This is true of cover plantings for farmlands. It is also true of forested areas and tree plantations. It is known that an interspersion of different vegetation types is needed to create "edge" areas that most game species require; it is not known which plant species should be employed for greatest effectiveness. In recent years, ecologists have put forth the idea that a mixture of species in forest plantings may have advantages (see Chapter Eight) from forestry as well as game management standpoints. At the conclusion of his study of food plants used by wildlife, Wilde pointed out:

> "The practice of raising bigger and better trees at the least expense has been in effect throughout Central Europe for about two centuries, but the results leave much to be desired. In the long run, the single-aged and single-species plantations do not have the ability to resist disease and insect pests. . .

"One way to avoid the European experience (perhaps on a much greater scale) would be to build the forest with all its natural associates from the plant and animal kingdoms, and not merely on a barren framework of lumber. The introduction of some secondary trees and shrubs, particularly those providing sustenance for birds and other animals, may have a greater indirect silvicultural influence than a direct bearing on game management."

The economics of mixed forestry has not yet been satisfactorily worked out. Mixed forests are difficult and expensive to plant compared to the plantations of single species. Procedures by which succession can be controlled have not been perfected. But from the point of view of fire control, disease, and insect infestation, mixed forests seem to have advantages over single-aged, single-species plantations. Even in soil fertility and water retention, a mixture of tree and shrub species has advantages. A layer of conifer needles decays but slowly and adds nothing to soil quality; it hastens water runoff. On the other hand, a mixture of needles and hardwood leaves quickly decomposes, forming a deep humus that returns nutrients to soil. Soil moisture is retained; rainwater is absorbed. Taking all things into consideration, future research may show that returns from mixed forestry can be markedly more handsome than from plantations of single species and single ages. The benefits to wildlife would be enormous.

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"Prior to agriculture, the quail was restricted mainly to the borders of streams and woods. A strip of hazel separated the prairie from the timber, and whenever the latter encroached upon the prairie, the hazel led the advance. It is evident therefore that both habitat and quail population were strictly limited. The advent of agriculture was soon followed by an apparently optimum ratio of wild to cultivated land. Reduction of burning permitted a rapid advance of hazel and other types of brush, while the building of fences and the planting of hedges increased greatly the protective cover. Cultivation produced grain and weed seeds, which in combination with cover, permitted the quail to take over lands that were formerly uninhabitable the year round."

—A. W. Schorger

"Game management is profitable if some major crop carries the land and if the environment need not be rebuilt—seldom if the game alone must carry the land, or if the land is ruined."

—ALDO LEOPOLD

Chapter Twelve

BOBWHITE QUAIL

HUMAN POPULATIONS, AT LEAST IN OUR TIME, SEEM DESTINED TO CONTINUAL increase. Not those of game birds and animals. Even without human disturbance, wild populations are sometimes subject to unusual declines, and they seem to be always subject to marked fluctuations. Scientists attempt to decipher the balance between births and deaths; the game manager to apply this knowledge to the maintenance of populations, and to the regulations that determine the percentage of the population to be harvested each year. To this subject of birth and death, and its meanings in terms of total numbers, is given the name population dynamics. Changes in food and cover, plus other things little understood and perhaps not yet hinted at, are reflected in changes in bird and animal populations from year to year. For some species, however, and the bobwhite quail is one, the factors limiting populations are relatively well known.

Some biologists have expressed the belief that quail moved north into Wisconsin with the coming of agriculture, but historical records uncovered by A. W. Schorger support the notion that the quail is native to the State. One thing is certain. Wisconsin's climate is such that life for quail—particularly during January, February, and March—is frought with hazard. In southern Wisconsin, quail reach the northernmost limit of their range; they are not to be found in the northern portion of the State. Even in southern Wisconsin—with the exception of a few years in the 1800s—quail have never attained the numbers characteristic of the southern states.

Shortly after the white man first settled Wisconsin, quail increased sharply in numbers. They were unusually abundant in the decade 1845–1854. In 1852 they could be collected literally by the bushel, and in 1853 they were found in cities, flying against buildings and into windows. A Madison newspaper carried a protest against hunting quail on the city streets. Quail were to be found in every grove, and a good shot could collect 50 to 75 in a day. In Milwaukee, the old records declare, there was an average of three coveys of quail to every 10-acre lot. As might be expected, a great commerce in quail quickly developed, and Wisconsin quail trappers and hunters sent tremendous numbers of these birds to cities as distant as Philadelphia and New York.

What caused such abundance? Franklin H. King wrote in 1882 that quail are birds of the "borders of groves, hazel patches, and open fields." In the time before Wisconsin's native vegetation was broken for farmland, quail were

restricted largely to the sites King describes, although they could also be found at times far out on the open prairie, remote from tree or bush. With the beginning of agriculture, food and cover for quail increased along fences and planted hedges. Oak openings grew into areas of shrub thickets and small trees. Grain and weed seeds provided ample food. Quail could live on lands that had never supported them before. During a decade, they had increased to numbers that would never be seen again. Market hunting, combined with a series of severe winters, caused a subsequent decline in the quail population, and although it had recovered somewhat by 1863, quail were never again to be as abundant as 10 years previously.

Serious scientific study of Wisconsin's quail—and of Wisconsin as quail habitat—began in the 1930s, largely under the direction of Aldo Leopold, and was conducted by a number of Wisconsin students, of which one was Paul L. Errington, an exceedlingly vigorous and acute field observer. Much of the University's quail study was conducted on an area near Prairie du Sac. During a 15-year period, 1929 to 1944, some 1,000 man-days were spent actually observing quail in every phase of life history.

Quail tend to remain within relatively small areas for protracted periods of time. If they cannot find food and shelter in these sites, particularly during winter, they must perish. However, the restlessness of spring sends the individual quail into new areas, winter coveys break up, birds pair for breeding, and this brings about occupancy of fairly large tracts of land that were unoccupied by quail during winter. Errington pointed out that when the breeding season is over, coveys re-establish, but birds sometimes do not rejoin their old covey.

This continual shuffling of individuals probably serves very important biological purposes. It reduces the frequency of inbreeding and it hastens discovery of new lands that have become suited to quail. Spring dispersal results in discovery and occupancy of new areas suited to nesting and even wintering. Quail begin whistling the bobwhite mating call in most of southern Wisconsin by the last of March, and coveys are breaking up and pairs forming from mid-April to mid-May. In Wisconsin, early nesting pairs select sites, very often on land where bluegrass is to be found. Birds selecting nests in midsummer pick any vegetation located in the open, yet affording some concealment. Bluegrass plots suited to quail are often found along roadsides, fencerows, and in woodland patches and old, grazed hayfields and prairie.

Quail are remarkably well-conditioned to the possibility that first nesting attempts in spring may fail. Half the quail pairs that Errington observed nesting in May or June had nests destroyed and were thus forced to nest again. Quail with bad luck in first attempts will renest later in the season and are then often successful. Mowing is the most destructive single agent, and mowing is usually conducted during the last half of the main nesting season.

One of Errington's major contributions to the field of wildlife management was his discovery, with Frederick N. Hamerstrom, Jr., of the importance of re-nesting

Both quail and pheasant depend on cultivated grain . . .

in bobwhite and pheasant population dynamics. In 1937, these two biologists published a paper reporting on work with the pheasant which substantiated earlier work by Errington in Wisconsin (and H. L. Stoddard in the southeastern United States) and which led to some entirely new ideas. As a result of this work, the importance of predators as destroyers of game—particularly of eggs and chicks—was seen in a new light. The fact that bobwhite and pheasants are capable of re-nesting, once or even twice, after the loss of first nests, renders the ultimate importance of predators slight indeed. The damage they do must be negligible.

For his work on predation, reported in a long paper in 1947, Errington received the annual publication award of The Wildlife Society. He had shared the same award in 1941 with Frances and Frederick Hamerstrom for a paper on the predatory habit of the great horned owl. On the importance of re-nesting in quail and pheasant, Errington and the Hamerstroms point out:

> "The evidence that a strong majority of the hens, by virtue of re-nestings, succeed in bringing off normally satisfactory broods in spite of heavy nesting losses suggests a reproductive resilience . . . that enables it to sustain in established range just about whatever breeding setbacks it may ordinarily need to . . . Nor has there seemed to be any clear connection between differences in kinds and numbers of nesting enemies and the intensity of depredations upon eggs as manifested from year to year . . ."

If any season of the year is critical, it is winter. Complete failure of a summer's nesting may not be as great a disaster as a severe winter. Errington's field observations showed that 80 per cent of the quail population can be killed during two weeks of particularly cold weather. Quail that fail to survive are those suffering wounds, disease, or hunger. Yet, most native northern bobwhites, if well fed and in prime condition, can withstand most of the low temperatures to which they are subjected, and Errington records instances of quail surviving temperatures of –15°, –24°, –27°, –30°, and –35° during winter cold spells. The dangers lie in snow so deep or crusted that food cannot be reached, and in lack of cover. He points out that there are many large, quail-vacant spaces where a few well-placed fencerow hedges or a few corn shocks would mean all the difference between no quail and perhaps two or three coveys.

> "Nature is most prodigal with the lives of those in which a minimum is invested. The destruction of a dozen newly-laid eggs early in the season may cost the species practically nothing. A dead day-old chick has not as much significance to the species as a dead bird that has reached breeding age. . . A given environment, year in and year out, can support only about so many birds. When the species has filled up the tolerable environmental niches, something has to befall the surplus—unless the environment is improved to accommodate it."

Wisconsin studies of quail populations have resulted in the formulation of one of the biological principles that govern the population dynamics of living things. Known as Errington's principle or the principle of inversity, its working is the result of an ability on the part of quail—and many other game species—to rebuild a decimated population. Winters may kill, but the individuals that survive are quick to take advantage of the favorable conditions of spring. According to

Errington's rule, the fewer the number of birds that survive into the spring, the greater will be the success of that year's breeding effort in terms of surviving young, and the greater will be the percentage of the summer's population increase. This principle applies to nearly all species. It is a law to remember.

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"You can't temporize with a deer herd. While we deliberate, they multiply. The reproductive force that brought the numbers of eastern whitetails from a few thousand to several million between 1915 and 1935 is still operating."

—DURWARD ALLEN

Chapter Thirteen

WHITETAILED DEER

A SUPPLY OF FOOD, PARTICULARLY DURING WINTER, IS THE FOREMOST PROBLEM FOR the majority of game birds and animals. The whitetailed deer is no exception. What has come to be widely accepted as the deer problem—as explosive a topic as any ever discussed by sportsmen and conservationists—is almost entirely a problem related in some way to the availability of winter browse. What constitutes browse? In which forest types is browse most abundant? How many deer can available browse support? How much damage do deer cause to the more valuable forest trees and seedlings?

These questions are of considerable importance to Wisconsin. Since early history, the whitetailed deer has been the most important of the large game animals found in the eastern United States. Wisconsin's deer herd has always ranked with the largest in the region. Its economic value is impossible to assess accurately, but it is surely one of Wisconsin's most important outdoor resources. A great deal of research has been conducted on Wisconsin's whitetailed deer by the Wisconsin Conservation Department. The University, historically, is relatively a newcomer to research on the deer problem.

It has been pointed out that deer possess remarkable recuperative powers and, when given reasonable protection, even very low populations will soon multiply to the maximal numbers that the land is capable of sustaining—and, unfortunately, to greater numbers than the land is capable of sustaining continuously. In areas where deer once existed, and exist no more, the reason for disappearance can usually be found in changes in vegetation and, hence, in food.

Deer were once more abundant in southern than in northern Wisconsin. With the advent of agriculture in the South, and of logging in the North, deer moved into new—and more favorable—territory. Young browse plants, growing where old mature timber once stood, were capable of supporting large populations of deer. But second-growth forests eventually reach maturity, and browsing pressure causes palatable shrubs to decline in number. Once this happens, deer can no longer reach the twigs and buds of trees; winter starvation is the result. In 1943, a committee of three scientists selected by the Wisconsin Academy of Sciences, Arts, and Letters (Aldo Leopold, Ernest F. Bean, and Norman C. Fassett) reported the result of a study of Wisconsin's deer problem:

> "Except in agricultural areas where deer have access to corn, alfalfa, or winter grains, deer subsist mainly on twigs, buds, and catkins of woody plants, i.e., 'browse.' The browse species differ in palatability. Many investigators have shown that palatable browse is nutritious browse, while unpalatable browse cannot sustain deer in winter.

"As a herd increases, the pressure on palatable browse plants weakens and ultimately kills them. It also prevents their reproduction, or the emergence of their reproduction above snow-level. Artificial plantings to re-establish browse are eaten up before they have a chance to grow.

"The unpalatable species are thus given a competitive advantage over palatable ones, and replace them. Thus, in over-browsed Wisconsin winter deer yards, white cedar, red maple, red dogwood, and ground hemlock, all palatable, are being replaced by alder, aspen, and white birch, all unpalatable.

"Trees above the reach of deer are browsed up to the level which a mature deer can reach standing upright on its hind legs (six to eight feet). The species of trees which show such a 'deer-line' are a sensitive index to the degree of deer-pressure and its duration. A new deer-line on cedar and none on balsam shows an early stage of over-browsing. A new deer-line on balsam plus an older one on white cedar shows an advanced stage. Fawns commonly starve at the stage when balsam or other poor foods show a deer-line."

Excessive browsing not only results in winter starvation, it also destroys the capacity of the vegetation to support many deer at all. Once alder, aspen, white birch, and balsam gain the ascendancy, it may take years or decades for more palatable species once again to achieve densities sufficient to furnish food for more than a very few deer.

Deer possess an innate behavior pattern that also works against them when winter closes in and food becomes scarce. Most animals, when crowded and hungry, begin to move about in search of food, sometimes covering enormous distances. But deer stubbornly refuse to leave a winter yarding area, even though it be devoid of food. Frederick N. Hamerstrom, Jr., has speculated that in pre-settlement times, wolves and cougars performed for deer a task they cannot now do for themselves. By chasing them from one winter yard to another, these predators brought whitetails into contact with new, unbrowsed vegetation.

There are, evidently, some practical reasons for this habitual congregating in yarding areas during winter. For one thing, deer can move about more freely where snow has been trampled and crust broken. Deer will feed outside the yarding area for some distance, but they invariably return to it. In a yarding area they find shelter, protection from chilling winds, concealment from enemies. Hamerstrom points out:

"To say that deer, like crows, concentrate in winter because they are gregarious is to state the condition, not to explain its cause. Still, if the term be taken to mean the tendency of individuals to band together for reasons phylogenetically so old that they can no longer be traced, it may be the only answer, however unsatisfactory."

Whatever the reason, deer will seldom leave one depleted winter yard to look for an unbrowsed one. It must suffice to say that problems posed by this behavior do exist; the solution to these problems rests upon the maintenance of populations that will not eat themselves out of house and home, and maintenance of yarding areas where deer can find palatable browse in sufficient quantities. Artificial supplementing of food merely sustains deer populations at excessively high levels. Deer possess digestive systems that require a variety of foodstuffs. They cannot obtain sufficient nourishment from one or two browse species or from artificial feed. Thus, artificial feeding does not take the pressure off the browse plants in wintering areas. Instead, even while artificially fed, deer con-

tinue to feed on browse, and as herds increase under artificial feeding, browse continues to disappear at an increasing rate. The land becomes progressively less able to support deer at all. The inevitable consequence is ever-increasing costs, ever-increasing herds, and inevitable mass starvation.

Wisconsin has been through one such cycle. It must be credited to Aldo Leopold that he saw, in the late 1930s, that the Wisconsin deer herd was going into a period of irruption and inevitable starvation similar to the initial stages of an irruption he witnessed in the Kaibab Forest in Arizona. Leopold predicted that unless the Wisconsin herd was reduced, starvation would follow, and he maintained his position despite almost unanimous and often bitter opposition. He pointed out that the increasing deer herd in the State was seriously damaging forest reproduction, a statement which was verified in 1945 by a study undertaken by the Lake States Forest Experiment Station and the Wisconsin Conservation Department. Leopold also pointed out that winter range is the limiting factor for deer populations. To maintain a deer herd without artificial feeding requires that the number of deer surviving into the winter should not exceed the carrying capacity of the winter yarding areas.

One recent research project has revealed the types of vegetation deer most often select for winter yarding areas. In the two-year period, 1952–54, two University of Wisconsin botanists, John T. Curtis and Earle M. Christensen, studied 258 stands of timber in northern Wisconsin and compared them in regard to vegetation type and the extent to which they were used as yarding areas. Curtis and Christensen found 197 of these stands to be used by deer, and comparing those used most with stands used least they concluded: "The more a stand is like the climax maple-beech forest, the less it is apt to be used as winter range by deer." In contrast, most lowland stands were subject to intense usage, with the exception of tamarack-spruce bogs. The potential carrying capacity of many of them was surprisingly great. Tree species found most often in these most-used winter yarding areas were white cedar, black ash, red maple, yellow birch, balsam fir, and hemlock. Lowland forests given the most intense use by deer were relatively stable forest types. They may change with time, but the changes are slow, and unless excessive browsing has taken place, palatable species are to be found in abundance. White cedar swamps—the single most important forest type used by deer for yarding—are particularly stable because of the ability of white cedar to reproduce by sprouting. Where flooding is a frequent springtime event, white cedar will sprout shoots from old fallen trees and even from branches of growing trees that touch the ground. This characteristic increases its value many times over species incapable of this kind of reproduction. Over-browsing, however, is particularly destructive of new cedar shoots. An over-browsed cedar yard is as unproductive of food for deer as a mature upland forest. Perhaps it may be possible to increase the productivity of cedar yards even under heavy browsing. If so, the method to do it has not yet been discovered. But only this, presumably, would increase the winter carrying capacity of northern Wisconsin for white-tailed deer.

Studies of wildlife diseases are conducted by scientists of the University of Wisconsin's department of veterinary science. Here two scientists diagnose a disease that afflicts the whitetailed deer . . .

Botanical studies of deer yards conducted by Curtis and Christensen, along with Grant Cottam, J. J. Jones, and James Habeck, all of whom took part in phases of the research project, have made possible the development of a method to gauge the severity of browsing pressure that is considerably more accurate than previous methods.

Instead of utilizing the condition of a few key browse species to estimate current browsing pressure, the new method gauges the effect of heavy browsing on many plant species and will be used to study the long-term influences of browsing on vegetation in lowland deer yards. The University research on deer yards has been supported as part of the Wisconsin Conservation Department's deer research project and is an application of facts obtained in the University's broad program of studies of Wisconsin vegetation.

The method will help botanists determine whether heavy browsing pressure speeds up the normal transition of one type of forest to another. The major succession route in northern Wisconsin lowlands is from tamarack and black spruce through white cedar and balsam fir, then through black ash to hemlock

and yellow birch, and finally to sugar maple and basswood. None of these stages is characterized by pure stands of any one or two species, but at each stage of the succession, these species or combinations of species are most abundant.

It is important to learn whether over-browsing speeds up normal successional processes. Deer prefer the white cedar and black ash stages of lowland forest for yarding areas. But over-browsing quite possibly speeds transition to later stages—and, thus, deer (in great numbers) may literally destroy their source of winter food and shelter. The study has not yet provided final answers, but some indications are already at hand. "No evidence concerning the future effect on the forests is available from the information now at hand, except that the quantity of cedar in yards is slightly below non-yards, a portent of the inevitable changes due to come in the future," the Wisconsin botanists point out.

Forest management practices which include rotation cutting should insure the existence of a variety of vegetation types for deer during warmer months of the year; brushy areas for browse, thickets for hiding and sleep, more mature forest for loafing, running, and escape. Winter harvest of forest trees for commercial use will provide increasing quantities of slash, which is helpful in providing winter feed for deer. Perhaps as forests mature and regular rotations are instituted, deer herds can be maintained at established population levels. Research on the whitetailed deer and on forests is designed to achieve an economical balance in the yield of these two Wisconsin forest products. Lowland winter yarding areas should be preserved as much as possible. Perhaps some method can yet be devised to make them more productive of deer browse. As Curtis and Christensen point out:

> "Whitetail deer have used these swamps as winter range from the earliest times for which historical records are available. During the exploitation of the forests, the swamps were cut, burned, and drained, but this reduction in the winter range of deer was not noticed because it coincided with the low point of the population of deer in Wisconsin. With growth of the deer herd, over-browsing in northern Wisconsin's ranges during winter has been almost universal. It is now evident that the winter range of northern Wisconsin will be a limiting factor regulating the size of the deer herd for some time to come."

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"Not only are pheasant population levels shown to reflect the general pattern of soils and crops, but also to reflect such seemingly unimportant details as the speed of mowing machines, the selection of hay species, the date of last cultivation, the maintenance of fences and ditches, and the social organization of neighborhoods . . . An equally intimate soil-farmer-animal relationship probably exists among numerous other birds and mammals, but remains to be explored."

—Aldo Leopold and Robert A. McCabe

Chapter Fourteen

PHEASANT AND HUNGARIAN PARTRIDGE

The ring-necked pheasant and the Hungarian partridge are both exotic birds—introduced from other continents to North America—and both were introduced into Wisconsin by the same individual at about the same time. Both are almost totally dependent upon agriculture for their survival in this State. The pheasant has become one of the most abundant and popular of southern Wisconsin's game birds; the Hungarian partridge has never been sufficiently abundant to attract much attention. What conditions account for this difference? Research studies on the pheasant are many and varied; only relatively few have been conducted on the Hungarian partridge. But these few do reveal at least some of the reasons for the partridge's failure to achieve abundance and for the contrasting success of the pheasant.

The Hungarian partridge was the first of the two birds to be planted in Wisconsin. In 1908, Colonel Gustav Pabst of Milwaukee began a series of introductions that were to continue through 1929. The partridges were obtained from Bohemia and released in five lots of about a thousand each in Ottawa Township of Waukesha County. It is believed that most of the Hungarian partridges in the State are descendants of the birds in these plantings, although other plantings —both by individuals and by the Wisconsin Conservation Department—increased the total number released in the State since 1908 to about 6,500.

Colonel Pabst made the first successful pheasant plantings in Wisconsin beginning in 1916. He planted 300 pairs of ring-necked pheasants per year for many years at Pretty Lake, near Oconomowoc. Within four years of the initial plantings, pheasants had spread over an area within a 10-mile radius, and by 1927, hunting was permitted in parts of Waukesha and Jefferson Counties.

The Pabst plantings were not the first in the State, but they were the first known to be successful. They were far from the last. At one time or another, pheasants have been released in all Wisconsin counties. They have survived where they were adapted to local climate and land management practices. They failed to survive where habitat was not suitable. In many parts of the State, wild pheasant populations can maintain themselves without restocking, provided they are not repeatedly subject to excessive hunting pressure.

The percentage of each sex and various age groups gives wildlife ecologists valuable hints on the population dynamics of game birds and mammals. From these Hungarian partridge wings, obtained through the cooperation of sportsmen, the sex and age of individual birds can be discerned. Data accumulated over many years will one day provide an improved understanding of the partridge and lead to better management practices to maintain this game species in Wisconsin.

This is not to say that any area in the State provides ideal conditions for pheasants. A 10-year study in the University's Arboretum points out that while pheasants can survive in Wisconsin, they do not reach the densities that pheasant populations elsewhere often do. Carried out in the years 1937–41 by Aldo Leopold, Theodore M. Sperry, William S. Feeney, and John A. Catenhusen, and during 1942–47 by Robert McCabe, the Arboretum pheasant study is the only one of its kind known to have been conducted on a mainland pheasant population that is largely protected from hunting (only pheasants that stray off the refuge are hunted).

For one thing, the Arboretum study resulted in improved techniques for trapping and banding wild pheasants. It revealed the extent of average pheasant weight loss during winter, and it showed that wintering pheasant flocks tend to remain in small, well-defined areas with little movement of individuals from one area to another. But probably most important, the study revealed that only 30 per cent of the Arboretum pheasants survive from one year to the next, despite the fact that they are unhunted.

This 70 per cent pheasant mortality in the University Arboretum is much greater than the mortality, for example, on Pelee Island. This island, located at the western end of Lake Erie, provides exceptionally favorable pheasant habitat, created by a soybean farming economy. University of Wisconsin scientists studying the Pelee Island pheasant population found that an average of 53 per cent of the hen pheasants live over from one year to breed the next, and no damage is done to the Pelee Island pheasant population by annual hunting losses of from 78 to 93 per cent of the roosters (each rooster pheasant breeds an entire harem of hens). As Allen W. Stokes, whose technical paper on the Pelee Island pheasants was accorded The Wildlife Society's publication award for 1955, points out:

> "Survival studies, by finding out when and to what extent mortality is occurring, should give important clues as to where to begin management. In South Dakota, severe losses from blizzards have indicated that winter cover is deficient. In Colorado, high loss of hens nesting in hayfields has shown the importance of providing safe nest cover. But over most of our pheasant range, we know little about the time, extent, or cause of mortality. The high survival on Pelee should serve as a yardstick for other areas. When survival proves to be considerably below that found on Pelee Island, habitat improvement would presumably meet with success."

Stokes adds, however, that until more is known about survival, development of habitat improvement methods must proceed largely by trial and error. One thing becomes apparent from studies conducted on the University's Arboretum and other areas of pheasant range in southern Wisconsin: Despite the fact that only 30 per cent—on the average—of birds making up one year's pheasant population live to breed the following year, reproduction is adequate to keep populations stable. And this occurs, too, despite the fact that only 16 per cent of the chicks hatched in spring survive until winter. In an average year, there are always many more pheasants living in the fall than can be expected to survive the winter. There are always too many pheasants for the food or shelter existing

after snow falls. How can the number of pheasants available for hunting seasons —and of those surviving each winter—be increased? There are more facets to this question than meet the eye. At present, there are no ready answers. Studies of Wisconsin pheasant populations are conducted under one of the University's continuing research programs. Projects on reproductive physiology have been carried on by Roland K. Meyer and Frederick Greeley (see Chapter Seventeen); Meyer, Irven O. Buss, and Cyril Kabat, former University research assistant who directs wildlife research for the Wisconsin Conservation Department, worked out techniques to determine the number of eggs laid by wild pheasant hens by counting the number of ovulated follicles in ovaries; techniques for learning the age of pheasant broods in the field were developed by Donald R. Thompson, former University research assistant, now chief of the Department's game inventory project, and Richard D. Taber. It is apparent from this that many projects have been conducted jointly by the Department and the University and many have been conducted by the University with Department funds. Another former University research assistant, Fred H. Wagner, now directs much of the Department's pheasant program.

In a research program sponsored by the University during the years 1936–39, and then continued, partly on federal funds, by the Wisconsin Conservation Department, Irven O. Buss, like Stokes, was led to the conclusion that habitat improvement was the key to larger pheasant populations. He writes:

> "In the 1920s, when the first wave of enthusiasm for pheasants swept over the State, the habitat requirements of pheasants were still unknown. Plantings were made in terrain now known to be hopeless, such as jack pine barrens and pine cutovers devoid of farms. The prompt disappearance of such plantings gradually pounded home the lesson that some parts of Wisconsin are unsuitable for pheasants."

Buss asked the logical question: What is it that makes a few counties (Winnebago, Fond du Lac, Dodge, Dane, Green, Rock, Columbia, Green Lake) capable of producing a surplus of 40,000 or more rooster pheasants each—a surplus that can be taken during hunting seasons without damaging breeding potentials? Buss concluded:

> "For a whole county to produce, it is necessary to have spots of cover heavy and large enough for winter use, not more than two or three miles apart. Winter food is no great problem, for if food is lacking, it can be supplied. The present trouble with pheasant range is that winter cover spots in many localities are too far apart to keep the summer range working. Drainage, marsh-burning, creek-straightening, and pasturing of marshes and woodlots are steadily reducing the number of winter cover spots, and hence increasing the distance between them. . . All recent trends and developments are hostile to the birds . . ."

The pheasant, which is almost totally dependent upon agriculture for survival in high densities, is limited by certain farming practices in the density to which it can attain. Most hen pheasants select open, grassy areas for nesting. Some hens nest early, when hayfields have not grown high enough to hide the eggs, but most hens nest only after the grasses have grown seven inches or more. Fields at least two years old contain more than three times as many pheasant nests as newly-seeded fields. In an average year, 35 of every 100 pheasant hens nest in hayfields—and 20 become victims of mechanical mowers.

While hayfields provide nesting sites that are favored by hen pheasants, they are extremely hazardous to incubating hens. Buss estimated that mowers are 11 times more destructive of nests than all nest predators combined, and 57 times more destructive than all other causes. For the pheasant—as it is for the bobwhite and the Hungarian partridge—a hayfield is a necessary, but very often destructive, part of the environment. Buss and others have advocated the use of devices such as flushing bars on mowing equipment to prevent some of the nesting loss and at least flush the hen. If flushed, hens will live to nest again.

With but one or two exceptions, these facts hold true for the Hungarian partridge. The exceptions, however, probably explain why the pheasant has reached high population densities in some parts of Wisconsin while the Hungarian partridge has generally failed to do so. For one thing, male and female partridge are indistinguishable when in flight. Both are subject, therefore, to hunting mortality, and hens suffer as great losses during fall as do the males. Second, the male partridge does not serve an entire harem of hens, as does the rooster pheasant, but pairs with one female for the breeding season. Thus, female Hungarians are incapable of serving—as does the hen pheasant—as a reservoir of breeding potential. The resulting lowered reproductive powers may account for the failure of the Hungarian partridge to reach populations in Wisconsin comparable to those of the pheasant.

In their six-year study of the Hungarian partridge in Wisconsin, Robert McCabe and Arthur S. Hawkins found that alfalfa fields are preferred nesting sites for hens, and that spring mowing for the Hungarian partridge—as for the hen pheasant—is a recurring disaster:

> "The time at which hay is cut is, therefore, important to the success of nesting, since cutting destroys nests, kills incubating females, kills broods (especially those that cannot yet fly), and removes cover for possible second nesting attempts. These periods, when plotted in relation to partridge hatching dates, show that the peak of hatching for the past six years has always been during the mowing period . . . undoubtedly one of the main causes of low density in the north-central states."

There is nothing anyone can do to change the time of haying. McCabe and Hawkins suggest, however, that unmowed strips in hayfields and unburned roadsides and fencerows would increase partridge nesting success.

Other influences, many of them not fully understood, may also play a part in the Hungarian partridge's reproductive ecology in Wisconsin, McCabe and Hawkins have pointed out. The partridge, for example, has been notably successful in the State of Washington, where hayfield conditions similar to those in Wisconsin exist. Perhaps differences in climate between Washington and Wisconsin are all-important in Hungarian partridge ecology. At any rate, comparisons of the pheasant and the Hungarian partridge in Wisconsin show that simple differences—some perhaps so subtle as to have so far escaped detection—often can make all the difference in the world. Both pheasant and Hungarian partridge are markedly dependent upon agriculture for nesting cover and the grain that makes up a major portion of their food supply. Relatively minor differences in life history, habits, and requirements of the two species bring about large differ-

ences in population densities of the species in Wisconsin, and the pheasant reaches high populations where the partridge does not.

Few introduced species are ever noted for the success with which they adapt to a new environment. Many that do succeed become serious pests—the starling in this country, the European rabbit in Australia, the black rat throughout the world. The success of the pheasant is a rare exception to both rules.

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These are named study skins, and they are prepared so a large number of individuals of the same species can be studied in the laboratory. This is the Old Squaw duck, often captured in deep-set nets of Great Lakes fishermen.

"One of the greatest traits of this practical age is the continual search for new truths. Yet, it is only recently, within the past 25 years, that sportsmen and wildlife administrators have realized the importance of research for more truth in managing wildlife populations."

—H. Albert Hochbaum

Chapter Fifteen

WATERFOWL

The decade of the 1940s marked the beginning of a new era in waterfowl management. Techniques were perfected to obtain information on duck breeding and migration; the effect of hunting on waterfowl populations was becoming clearer; the importance of certain land areas to waterfowl breeding success was established beyond doubt. With this new knowledge, the day has moved closer when waterfowl will be managed with the greatest possible effectiveness, and when season and bag limits can be set with confidence that sufficient brood stock of all species will survive hunting seasons and be capable of restoring the population the following year. What is now the practical art of waterfowl management will become an applied science.

A tremendous annual replacement is required of waterfowl populations. For this reason, the preservation of waterfowl breeding lands is the single most important aspect of waterfowl management. Hunting can damage waterfowl populations, but the population has a chance of recovery, providing only that some ducks survive. Once breeding lands have been destroyed, however, waterfowl are usually gone for good. The drought of the 1930s resulted in great declines in the productivity of waterfowl breeding lands simply because these lands dried up. Many sportsmen and biologists despaired that the decimated waterfowl populations would ever recover. They did—and, in a sense, the years of scarcity were profitable because they clearly demonstrated a need for waterfowl management, and they resulted in a tremendous stimulus to waterfowl research. They also resulted in some concrete efforts to preserve, improve, and create impoundments for breeding waterfowl in the American prairie states and the Canadian prairie provinces.

The potential of these lands for waterfowl breeding can be protected by wise land management. And wise land management means prevention of marshland and pothole drainage. It also means replacement of drained areas with suitable artificial impoundments to furnish breeding habitat, such as have been created and maintained by Ducks Unlimited (Canada). Countless small potholes on the vast prairie lands of both Canada and the northern United States provide the key to waterfowl production. If they are drained, they have been destroyed; and gone, too, are the waterfowl that might have bred there.

Economic pressures and the inertia that blocks efforts to revise old customs of land management have, in many instances, prevented the application of existing knowledge. Some very important aspects of duck ecology have yet to be studied, but probably more is already known about waterfowl than about any other

single wildlife resource. Unfortunately, putting knowledge of waterfowl into practice is often more difficult than doing the same for other game species. University research programs, however, continue to reveal useful facts on the State's waterfowl resource. At the present time much of the effort to put these facts to practical management use in Wisconsin is directed by a former Wisconsin research assistant, Laurence R. Jahn of the Wisconsin Conservation Department. Of the need for greater acceptance of research findings, H. Albert Hochbaum, former University of Wisconsin research assistant who now directs the Delta Waterfowl Research Station, writes:

> "The most important tool of management today is education to show the landowner—whether municipality, county, state, province, or farmer—how to use the land without destroying its resources. . . I count the educational program of Ducks Unlimited, which is making the people of the prairies conscious of their wealth in marshland, their greatest achievement."

Although much of the University of Wisconsin's program of waterfowl research has been conducted within the State, perhaps the greater portion of the work has been done at the Delta Waterfowl Research Station, situated at the southern tip of Lake Manitoba, northwest of Winnipeg. The Delta Station was organized in 1931 by a Minneapolis industrialist, James F. Bell, and a few years later the basis for participation by Wisconsin and other university scientists was laid when Bell, Aldo Leopold, William Rowan of the University of Alberta, and Miles D. Pirnie of Michigan State University drew up a plan of cooperation with the North American Wildlife Foundation (then the American Wildlife Institute). The Foundation now supports the research at Delta, largely with funds supplied by private and industrial donors. Leopold and others served as advisors to the program, and since the close of World War II, the Delta Station has been the center of waterfowl research for six American and Canadian universities including Wisconsin and for both federal and dominion wildlife organizations. Many scientific papers and three books, *The Canvasback on a Prairie Marsh*, and *Travels and Traditions of Waterfowl*, both by Hochbaum, and *Prairie Ducks* by Lyle K. Sowls, (given the 1956 publication award of The Wildlife Society), have so far been published on the research at Delta. Many additional papers await publication, are planned, or are in progress. Sowls, like Hochbaum, was trained at Wisconsin, and served on its research staff before going to the Delta Station. Hochbaum writes:

> "The conclusions at hand are but a beginning. As pressures against the birds grow year by year, we must apply this knowledge to control the variable factors affecting the waterfowl populations. The primary objective is to expand the renewability that is inherent in this valuable waterfowl resource. The goal is to accelerate population growth—to combat limiting factors with wise management and use."

Hochbaum's *The Canvasback on a Prairie Marsh* was the first publication to reveal what fraction of the waterfowl population or hunting bag represents young birds of the year. It was the first comprehensive report on the Canadian breeding season. It was also the first study to show that an unbalanced sex ratio (more males than females in the population) is produced by environmental hazards which are greater for the female than the male. Hochbaum also revealed some of the influences at work when ducks select nesting territory, and he pointed out that the males segregate on moulting lakes after the breeding season

has passed. For this work, Hochbaum was given the 1945 publication award by The Wildlife Society and the Brewster Medal of the American Ornithologists' Union. Sowls' book, *Prairie Ducks,* is, in a sense, a companion volume to Hochbaum's, and reports on Sowls' study of surface feeding ducks, while Hochbaum's work was largely with the diving species. Sowls expanded existing ideas of territoriality in ducks—selection of nesting sites and defense of areas around them. He studied how widely individual birds ranged, the extent of nesting mortality, and the capacity of ducks to renest successfully after predators have destroyed first nests.

Hochbaum's next volume, *Travels and Traditions of Waterfowl,* is an exposition of a theory of waterfowl navigation, and of the evidence supporting Hochbaum's belief that breeding regions can become "burned out" if ducks that traditionally use them are killed or otherwise kept from breeding until no survivors remain. If a marsh's duck population dies out, Hochbaum believes, years may elapse before the area once again becomes a traditional breeding ground for another duck population. For a region to be occupied by migrant waterfowl at some stage of the annual life-cycle, living ducks must hold its memory in mind, and consider it a traditional end-point of migration. This, Hochbaum says, accounts for the fact that some suitable areas that once held large breeding populations no longer do so.

Knowledge of basic breeding ecology of waterfowl has been obtained largely by research programs such as that at Delta. In contrast, knowledge of the effect of hunting season lengths has been gained largely through trial and error methods, practiced since the first waterfowl hunting laws were passed. When ducks seem numerous, seasons are made longer, bag limits larger. The actual percentage of the duck population that falls to hunters' guns is unknown—although modern methods have permitted some reasonable estimates. Biologists have developed methods, crude though they may yet be, to estimate whether populations are increasing or declining, but actual duck numbers are still anybody's guess. Summarizing the available information, Joseph J. Hickey has written:

> "Rates of duck mortality are relatively high in the mallard and black duck, intermediate in the diving ducks, and lowest in the teal. About 28 per cent of the adult mallard population in the Mississippi Valley area is estimated to die from hunting in an average year. This appears to be about as much as the population can stand, but under present conditions the hunting mortality rate will importantly fluctuate from year to year and locally be excessive. The governing variable for a given year is weather, which can so influence the migration of some ducks as to double the rate of harvest of one year over another or reduce it 50 per cent even with the same set of regulations. . . Modern bag limits and seasons are in this sense set up on the basis of average conditions. They are relatively crude management tools which are known to be effective in the long run."

The information on these points has been obtained from an enormous banding program carried on during the past 30 years. The U.S. Fish and Wildlife Service has issued bands and kept records of band returns since 1922. These records have provided considerable information on hunting mortality along the fall migration flyways of the North American duck species. Working with these returns, Hickey found that hunting regulations and fall weather conditions are the two most important factors influencing the annual kill of mallards and pre-

sumably other species as well. At the present time, large numbers of both adult and young ducks are banded on their summer breeding grounds in Canada. Bands returned by hunters furnish one of the best methods yet devised to estimate waterfowl populations and hunting mortality. As more figures become available, it will be possible to predict with even greater accuracy the number of ducks that survive any given combination of weather and hunting season regulations.

Hickey points out that hunting mortality replaces natural causes of death in waterfowl populations, and is, in a sense, a form of predation. At present, adult mallards are being harvested close to the maximum possible without harming breeding potentials, but many other species are harvested at a markedly lower rate. Here the problem is to find ways to take other species to a greater extent without also harvesting more mallards.

> "This is also a human—not entirely a biological—problem. What waterfowl managers need today is public acceptance of the freedom to experiment, and willingness to allow experiments to be carried out locally. Any design for a harvest system for ducks is considerably complicated at the present time by the necessity of applying old rule-of-thumb experience, by the need to rely on long-range weather forecasts to help set regulations to be in effect 60 to 120 days later, and, finally, gradual losses in nesting habitat and slow declines in the average number of ducks available."

This latter problem—losses in nesting habitat—is by far the most serious threat to waterfowl resources. The wealth of information now available on waterfowl ecology—the result of research at the Delta Station and on other waterfowl areas —is valueless without protection of spring breeding areas and wetlands along fall migration routes. If biological research has pointed up a cardinal rule for waterfowl management, it is that land and water suited to ducks must be preserved if populations are to be maintained. In the United States, federal and state purchase of refuge areas along migration routes has encouraged those persons who would like to see broad waterfowl programs, but generally this has been one of the neglected fields of wildlife management. The problem becomes more difficult to solve because waterfowl values seldom can be stated in monetary terms. As Robert A. McCabe points out: "It is hard to understand why we establish laws to manage waterfowl, yet allow the destruction of entire marshes with ditch and tile." Where economics is a factor in land use, it is hard to say which land shall be devoted to waterfowl, which to other uses. But as a possible answer to this problem, McCabe has advocated setting up county drainage committees to pass on proposed projects, the registering of drainage equipment to eliminate transient operators, and a farm game-crop law to encourage the production of wildlife just as the forest-crop law encourages the production of trees. This latter possibility has also been discussed by Walter A. Rowlands:

> "There is today among our many sportsmen and wildlife groups a mounting pressure for hunting areas and a supply of game animals large enough to satisfy the demands from the densely populated sections of the State. . . Wisconsin has today a fine network of federal, state, county, town, and community and school forests as well as a rapidly increasing area of industrial forest development program. It turned out that there was room for both farms and forests. . . There are, I believe, two essential principles required for the development of game areas, whether for deer, sharptails, or ducks. *One,* wherever and whenever our game people feel the best environment exists for the development of game areas of any kind, it is important that local citizens, local government, and local organizations be considered and consulted in the development

part of the planning process, their views obtained, and their cooperation secured. *Secondly,* somehow the cost of developing such an area must be financed in such a way that local government be not required to bear the total burden of loss of taxation of these lands. The principle of the Wisconsin Forest-Crop Law ought to be studied as a possibility for eliminating local financial hardship to the community. This law has been in use for 22 years in 27 counties—and it works.

"Almost every county in northern and central Wisconsin has some unused lands which can be developed for these increasingly important game and wildlife areas. Many of these lands are unsuitable for farming purposes and are not eligible for entry under the Wisconsin Forest-Crop Law. As we increase our knowledge and appreciation of the development and use of all our natural resources, we are beginning to get a better understanding of a balanced use of land, some for farms, forests, game, recreational uses, and of industry based on each of these uses."

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Two male prairie chicken (the second male is in the background) display for a female (at right) during the spring mating dance. The two feather tufts on the heads of the males are raised, and the air-sacs of the neck are inflated during the *booming* performance, as it is called.

"This is a Township of barrens that is almost worthless for agricultural purposes, or anything else, as there is but very little Timber in it, and that is scrubby Black Pine; and there is hardly a drop of water in the Township, in fact now, except small ponds in the South end of it, the Prairie that I have noted on the West Side; can hardly be called a Prairie, as no very great time has elapsed since it was covered with small Pine which has been blown down, and burned up, remnants of which still lie on the ground."

—From a *Surveyor's Journal:* 1856. A Description of Southeastern Bayfield County

Chapter Sixteen

THE WARY GROUSE

Two of Wisconsin's grouse species—the sharptailed grouse and the pinnated grouse or prairie chicken—are now haunting relics of a bygone day when Indians ranged the prairies and the low booming sound of mating grouse on distant dancing grounds was an early harbinger of spring. Purchase of some lands and prairie grouse management measures have been undertaken recently in Wisconsin in an effort to preserve these grouse from extirpation. If they fail, the State's prairie chicken and sharptailed grouse will join the ranks of the passenger pigeon, the elk and buffalo; they will be among the wild species that were once abundant in Wisconsin and are found no more. In any case, the decades of the 1940s and 1950s will go down in Wisconsin wildlife history as the low point in the fortunes of these species. The greatest obstacle to efforts designed to preserve them is lack of public knowledge of the value of Wisconsin's wild prairie grouse, or even that they exist. Most of the people who compose living generations have never seen a prairie grouse, nor have they heard of the time when "two hunters with one dog generally secure 50 to 80 birds in a day," an historic fact recorded in the papers of Dr. P. R. Hoy of Racine. An early naturalist, W. W. Cooke, wrote of Buffalo County: "Of the prairie chicken and grouse family, what an abundance nature furnished us!"

In his historical studies of the grouse species, A. W. Schorger expresses the belief that in pre-settlement times the prairie chicken inhabited the vast open prairies of the southern half of Wisconsin, and the "sharptailed grouse was to be found actually or potentially in all parts of the State." It is generally accepted that the numbers of prairie chickens increased with the advent of pioneer agriculture in southern Wisconsin, the partial result, at least, of a decline in frequency of prairie fires. Logging, fire, and farming opened up great expanses in the northern counties of the State and made them available for both prairie chicken and sharptailed grouse. With grasslands, plus grains for winter feed, prairie chickens extended their range until they were to be found in every county. Then, as northern grasslands evolved into brushlands, prairie chicken numbers declined and sharptails took their place, eventually reaching great abundance. "The prairie chicken reached Lake Superior due to the felling of the forests and the opening of farms," Schorger writes. And then, as the forests grew back, the

land once again became unsuited to prairie chickens. Schorger also points out that many of the marshes of the Central Plains were drained in the vain hope of obtaining a permanent agriculture, and these drained lands with their abandoned farms have reverted—or are reverting—back to brushland. Thus, in both northern and southern Wisconsin, sharptails find suitable habitat in the wake of the prairie chicken, but eventually brushlands are invaded by aspen, oak, and pine and become suited only to Wisconsin's third grouse species—the ruffed grouse, the popular "partridge" that explodes underfoot from forest thickets and puts both hunter and dog to the most exacting test. On the sport of ruffed grouse hunting in Wisconsin, the naturalist Edwyn Sandys wrote in 1902:

> "Imagine a long, easy sun-kissed slope in the most beautiful section of the magnificent Badger State—time mid-afternoon. Half of this slope is gleaming stubble which rolls in sleepy, golden billows to a strand of dull crimsons and cooling bronze, where the waist-high scrub oaks and briars and dwarf hazels weave together, glowing like some huge rare rug of Orient spread over the everlasting hills. Beyond all this, stern ramparts of grim grey stone hearsed with sombre pines, beneath which trail heavy crimson banners of creepers, as though flung earthward in grief for the passing glory of the year. . . Along a certain Wisconsin steep runs a peculiar step-like formation—a smooth pathway one third of a mile long. Upon one side, and for many feet above, rises a huge slope of forested rock, which, upon the outer side of the path, falls away into a dim ravine, so deep that only the tallest of its tree-tops rise above the level of the path. . . The ruffed grouse love such places as they love the old logging roads and ancient trails."

In Wisconsin, research on ruffed grouse has lagged until the last few years: for one reason, the species is in no danger of extinction. It is found in all but a few counties, and were it not for the mysterious, cyclic ups-and-downs to which the ruffed grouse population is more conspicuously subject than other grouse species, it would present only minor management problems. It is a bird of the young forest and nearly perfectly adapted to a state where forests are a prime industry. The fact remains, however, that ruffed grouse populations are cyclic. Every 10 years, on the average, populations decline to such an extent that only rarely is a bird seen in autumn. The cause of these cycles—they also occur in other bird and mammal species—has long been a profound biological mystery, so profound, in fact, that only recently has any light been shed on possible natural events bringing the cycles about (see Chapter Seventeen). This obscurity of cause for so obvious an event probably has discouraged many potential research projects in ruffed grouse. There are other reasons for discouragement. The grouse themselves are baffling research subjects. They inhabit areas in which it is difficult to watch them. They are wary and solitary birds that make their presence known only by resounding wing beats as they flush or by the muffled thump of springtime drumming. New research techniques being developed now by Robert Dorney, student and Wisconsin Conservation Department biologist, show promise, however, of providing information which may improve ruffed grouse management in the State to a considerable extent.

In contrast to the limited information available on the ruffed grouse, research on the prairie grouse and sharptail has a long and fascinating history, not unmarred by tragedy. In 1928 the research bureau of the Wisconsin Conservation Department was organized and eight Wisconsin citizens were appointed to its governing board on the basis of their knowledge of conservation problems and research needs. Dr. Merritt L. Jones, a Wausau surgeon, was appointed bureau

supervisor, and the members were Paul D. Kelleter, State conservation director; Profs. George Wagner, F. G. Halpin, and L. J. Cole of the University; Dr. W. D. Stovall of the State Laboratory of Hygiene; and C. L. Harrington, B. O. Webster, and William F. Grimmer of the Wisconsin Conservation Department.

Dr. Jones initiated the prairie chicken study by obtaining the services of Alfred O. Gross of Bowdoin College, an ornithologist who agreed to spend some time investigating the grouse problem in Wisconsin. Gross worked on this study as time permitted in 1928 and 1929, and then in 1930 he hired an assistant, Franklin J. W. Schmidt, a graduate of the University of Wisconsin with an intense interest in wildlife, who had already gained some recognition for his work on mammals. The study of grouse and of the central sand plains area of Wisconsin became Schmidt's absorbing interest. When Gross returned to his duties at Bowdoin after writing a detailed progress report on the grouse study, Schmidt was put in charge of the project. It was continued until 1933 when available funds had been expended, and then the newly-established Department of Wildlife Management at the University offered Schmidt a fellowship. Schmidt fulfilled an engagement to accompany a Field Museum expedition to Guatemala and upon his return to Wisconsin in 1934, he continued his research on the grouse, completed manuscripts of eight scientific papers, and was planning a book which, very likely, would have ranked with the best in the field of natural history and ornithology. He died in a midnight fire at Stanley, Wisconsin, August 7, 1935, while attempting to save the manuscripts, photographs, and notes accumulated during half a decade of work.

A summary of Schmidt's contributions to scientific knowledge appears in the first chapter of *Wisconsin Grouse Problems,* a volume written in 1948 by Wallace B. Grange, game biologist noted for his research on the native grouse species which he conducted as a member of the Wisconsin Conservation Department. And in an introduction to Schmidt's only completed paper that escaped the fire, Aldo Leopold penned these words:

> "Society has not withheld its gratitude from the geographical adventurer who failed to come back, nor from the scientific explorer who dies in the course of an unfinished quest. It should, I think, at least know about important fatalities in the new argosy of the intellect which seeks not the conquest, but the preservation, of nature. . . As his biographer I can only affirm the personal opinion, unsupported by those burned documents, and admittedly biased by the pain of a lost friendship, that Franklin Schmidt knew more of the life history and ecology of the prairie grouse than any living man, and as much as any living ecologist knows about any American game bird. Likewise that he had developed a deep understanding of the interactions of ecological forces, and the mechanisms of their integrated expression in the life and landscape of Wisconsin. It is no uncommon thing for a specialist to sound a record depth of knowledge in a single limited field, but it is a rare and inspiring thing to see one putting together a mental clock made of parts from the whole gamut of earth-sciences, and then listening for it to tick.
>
> "Schmidt's particular hobby was the marsh region of central Wisconsin—that waif of the slums of exploitation, long since cast out as an economic ne'er-do-well, but now the subject of uplift by many conservation bureaus. If and when the intrinsic loveliness of those vast wastes is duly appreciated and restored, the mechanism of restoration will be set upon foundations of ecological understanding built in large part by Schmidt."

Fortunately the chapter on sharptailed grouse and prairie chicken does not end with the Schmidt tragedy at Stanley, Wisconsin. Financial means to revive the study were lacking, but in 1936 Leopold proposed that the University act as a

clearing house and supply depot for other agencies if they would trap, band, and feather-mark prairie chickens. A gratifying response was forthcoming and in March, 1936, Leopold wrote that "the trap line extends from Baudette, Minnesota, through Wisconsin to Central Michigan, and is operated by nearly all wildlife agencies of the North Central Region, both state and federal. . . There has been mobilized the skill, enthusiasm, and equipment requisite to an interstate attack on the problem in future years."

Possibly of greater eventual importance was the fact that a student named Frederick N. Hamerstrom, Jr., caught, banded, and feather-marked a score of sharptails and several prairie chickens near Necedah, Wisconsin, as part of that project. In 1937 the study of pinnated and sharptailed grouse was resumed with Hamerstrom as project leader, the beginning of work that has provided much of the information now available on these two grouse species. First as students, then as biologists for the Wisconsin Conservation Department, Frederick Hamerstrom and his wife, Frances, have made as thorough a study of the two prairie grouse species as has been made of any American game bird or animal. From their farmstead near Plainfield, the center of operations, they have conducted banding experiments, made exhaustive studies of spring booming ground behavior, and conducted food and habitat surveys. They have provided knowledge by which final extinction of these species in Wisconsin can be averted—if the knowledge is applied quickly enough. At the 1954 convention of the Wisconsin Society for Ornithology, the Hamerstroms summarized their work on these species as follows:

> "The spectacular quality of the rise and fall of the prairie chicken in Wisconsin, like the rise and fall of the Roman Empire, is a matter of historical record—a record pieced together by ornithologists, hunters, botanists, and geographers. The evidence is sometimes indirect—tree rings tell part of the story, early settlers' accounts and old newspaper items tell the rest. The archeologists have played a part in describing the extent and probable frequency of Indian fires.
>
> "It is not unlikely that early waves of settlement brought about a temporary increase in prairie chickens in the southern part of the State. Like moths invading a carpet, the prairie chickens spread throughout the entire State. That this tremendous spread can be attributed to the white man is indisputable—as indisputable as that the loss of range since the turn of the century is also the white man's doing. The influence of the white man upon the prairie chicken has been enormous. He has caused millions to be born; and more recently he has been the cause of millions unborn. The powerful influence of our civilization upon this species has been inadvertent. State and private food patches and land management have been a step in the right direction. Few people in Wisconsin realize that the majority of the prairie chickens are produced inadvertently. This would be fine if they were not progressively losing out, for they are losing their nesting cover, a surer form of death than any major catastrophe. If the people of Wisconsin will support the preservation of nesting grounds, we believe the species will be secure and may even increase. Once the remaining flocks are reduced to a handful of scattered birds, it may be too late."

The story is a similar one for the sharptailed grouse—with a few revisions. The quantity of land area suited to sharptails was greatly increased by lumbering and fire, and the sharptails were quick to invade the logged and burned areas growing back to brushland and early stages of second-growth forest. These vegetational changes had yet another influence on the sharptails. The Hamerstroms have pointed out that conditions now permitted sharptails to abandon ancestral traditions of long-range migration from open-land breeding grounds to brushland

Trapping and banding prairie chickens during winter . . .

wintering grounds. In early days, grasslands and forests existed in large, extensive blocks. For sharptails, the migration from one to the other was accomplished only by long flights. Logging, however, created more openings spaced closely together in the forest, so that the sharptails' seasonal migrations could be accomplished by shorter, easier flights of perhaps a few yards or a few miles at most. Sharptails, thus, have been and are remarkably adapted to Wisconsin's northern field and forest, but some management practices in this area must still be undertaken on the sharptail's behalf. As the Hamerstroms point out:

"The objective is essentially to maintain openings, low brush, and scattered thickets. A forest rotation based on clear-cutting of some areas would benefit sharptails primarily during the early stages shortly after cutting, but would have value for ruffed grouse and deer for an even longer period in each cutting block. In other words, in no case could costs be charged wholly to sharptail management."

Wisconsin has reached the stage of development where another valuable group of wildlife species is now in danger of extirpation, just as the elk, buffalo, turkey, and passenger pigeon were endangered in another day now long past. An important distinction can be made, however, between the past and the present. A few measures—revealed by research and already shown practical on some small areas —not only can save these grouse species, but might possibly render them sufficiently abundant to constitute a real economic wildlife asset, one that could help preserve in Wisconsin the recreational and wilderness values which have been

long lost elsewhere. It would be to Wisconsin's credit that these species—and the lands upon which they live—be managed wisely for all time.

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An observation tower, or blind, is used to observe the Arboretum's bird colonies . . .

"The early organic chemists must have felt very much as the animal ecologist does now. It must have seemed dangerous and vain to look beyond, say formaldehyde or the benzene ring, toward higher complexities. Yet organic chemists now seem to move with great confidence amidst compounds of complicated structure, built together by steady research upon related chemical compounds and on the general properties of such systems."
—CHARLES ELTON and RICHARD MILLER

Chapter Seventeen

INDIVIDUALS, SPECIES, AND POPULATIONS

BIOLOGICAL SCIENCE HAS PASSED THE STAGE OF DEVELOPMENT IN WHICH RESEARCH devoted to bare descriptions of the appearance of plants, birds, animals, and landforms holds much promise of revealing new and useful facts. With the exception of the insects and the plants, there are probably few species that have not been discovered, named, and assigned at least a tentative place in the scheme of orders, families, and genera. Their role in evolution has been deduced, at least to some extent, and described. We are, thus, quite familiar with the multitude of species that make up the living world. But we have only begun to study the ways by which plants and animals live as individuals and as part of the world of life. Man has acquired some broad ideas of basic physiology, but the chemistry of living things is only now beginning to yield up its most important secrets. The complexities of the living chemicals are so profound as to stagger the imagination. Yet, we have evidence to support the hope that, within a few decades, life chemistry will be understood, at least in outline, to a fairly complete degree. With greater understanding of what happens within the living organism, there will be greater opportunity to understand the relationships existing between the plants and animals—and human beings—that make up the living world.

The sciences of physiology and biochemistry reveal the internal adaptations life has made to the world around it; the mechanisms of the trigger chemicals known as hormones; the chemical pathways of substances eaten for energy and stored in tissues as fat; the myriad chemical feats accomplished as everyday events by the physiology of life. Biology, in another of its branches, has entered an era in which life and living things are studied as parts of a vast symphony of relationships in which all species are linked together. These two branches of biology —physiology and ecology—are actually not so far apart; both are studies of adaptation, of adaptation by chemistry and adaptation by form and behavior.

Man, by his presence (in increasing numbers) and by his works, often unwittingly disrupts the balance that centuries of adaptation and evolution have built between and among species. Or he may do so in the urgency of need for food and shelter. The temporary result is often a greatly increased ability to extract useful commodities from the land. But eventually the capacity of the land to produce, even at a much lowered rate, is destroyed. It seems reasonable to hope

the science of ecology will provide an understanding of native plant and animal species that will enable man to render marginal and wild lands much more lastingly productive of things we value—trees, wildlife, and opportunities for recreation and esthetic appreciation.

Biologists have come to see that native animal species are seldom in direct competition with one another. In many instances, habits overlap—both deer and cottontails, for example, consume the same types of browse—but it cannot be said that these species compete. Both attempt to obtain a share of available wealth, but in different ways. They occupy different ecological niches. Deer eat material rabbits cannot reach. Rabbits eat vegetation that deer ignore. Some bird species nest on the limbs of trees, others in shrubs, cliffs, and mud banks, tree stubs, marshes, or prairies. There are, in fact, nearly as many different sites used for nesting as there are species of birds. Each species nests only on a site that is typical for its species. Each, in other words, occupies a niche in nature—a well-defined place in the scheme of things, where it is as far from direct competition with other species as it has been possible for it to get.

Research reveals the mating, breeding, feeding, and living habits of the species that make up the web of life. It also reveals the needs of individual species in terms of food and habitat. It helps elucidate the basic biological laws operating throughout the world of animate nature. An understanding of these laws finds application in man's management of the world's renewable resources, among them game birds and mammals.

Every time a male ruffed grouse drums in springtime, for example, he proclaims that he is territorial; that he seeks or has staked a claim. Once his claim has been established, other male ruffed grouse are not to be tolerated within its borders. The maximum population that male grouse can attain on any given area, then, is limited to the number of territories that the area can be divided into. Any surplus of males will quickly be driven out of the best areas into sites where chances of breeding success are reduced. Competition exists between individuals of a species, and it can be severe, but it seldom exists between members of different species. A male ruffed grouse will drive other males from his territory; he takes little note of a pileated woodpecker nest in a hollow tree above him. The fact of territoriality, however, has important implications for the management of wildlife. Any given wild area will provide only a certain number of territories for the individuals of each species found within its limits. Counts have been made of the numbers of plants and animals, predators and prey, found in typical wild communities, and of the relationships between them. These are often termed food-chain studies, for they demonstrate the manner in which energy derived from plants is ultimately distributed, first among herbivores and then among carnivorous creatures.

For wildlife, predation is a fact, and often a way, of life. Most species can be divided into two groups, predators or prey. Many of Wisconsin's economically valuable game species fall into the latter group. Predation, for this reason, becomes a subject of considerable interest, and has been emphasized in Wis-

consin's wildlife and ecological research programs. In his study of the bobwhite quail, Paul L. Errington found that predators are often responsible for the decline of quail populations during winter, but that quail decline only to a level established by the availability of good cover. Quail that are able to locate protective cover can survive nightly hunts by foxes and owls. Birds that are unable to find or compete successfully for suitable places to hide are discovered and captured. The same principle holds true for whitetailed deer, although adequate food is the most important predator-protection for wintering deer. In a study of Oneida County's remnant wolf packs, Daniel Q. Thompson found that the deer population increased at the same rate over a five-year period (1935–40) in areas where wolves were present as it did in areas where there were no wolves. Over this period of time, the deer in Thompson's study areas increased from 10 to 30 deer per section, typical for Wisconsin deer range during a period of rapid population growth.

In a study of waterfowl nesting, Lyle K. Sowls found that 19 per cent of duck nests at the Delta Waterfowl Research Station were destroyed by the Franklin ground squirrel and 21 per cent by crows. Of all the studies by Wisconsin scientists, only this one ever demonstrated that any predator destroys a sizable proportion of the population of its prey—and the prey, in this instance, consisted of eggs which would most likely be replaced during renesting attempts.

What these studies mean in terms of predator control is simple. Most biologists today consider bounties uneconomical, at least as far as the protection of game birds and other animals is concerned. The only real damage a predator may do is confined to the destruction of domestic animals. The studies pioneered by Errington have shown that predators are not influential in determining the abundance of game. The larger game animals—deer for example—have "a propensity to increase up to the limit of the food supply and to the extent of actually starving" whether predators are present or not. The implications for predator control legislation are obvious.

Studies of the mechanisms by which species are balanced, one with the other, are especially valuable to biologists who attempt to maintain or increase populations of one, two, or a dozen useful wild species. They are essential to ecologists who would understand the basic principles of behavior, habit, and adaptation that govern communities of living things. These same principles apply to human populations, in many instances, and ecology has already begun to include the study of human populations within its province. As a science, ecology holds promise of being of value in the wise government of human affairs as well as the wise use of renewable resources.

Ecology is the study of the relationships of living things to other living things and events in the world around them. Physiology—or much of it—concerns an organism's internal chemistry and its adaptations for successfully meeting challenges that the outside world presents. There is no clean-cut line separating the two sciences. Animals behave as they do because of physiological and hormonal controls over life chemistry. But this chemistry is adapted to the kind of life the

animal leads and has led—it is as much the product of evolution and adaptation as is behavior. Wisconsin's research program has included many fundamental and significant studies on the nature of these innate controls found in all living things, and the role they play in population dynamics.

Some studies of artificial communities of wild animals have shown that natural populations have some unusual inner checks on growth which come into play when the population outruns its food supply or over-runs the area available to it. John T. Emlen, Robert L. Strecker, and Charles H. Southwick have worked with wild mouse populations and demonstrated that mice confined within an enclosed area cease reproduction entirely when the population reaches a point where all available food is eaten every day. As populations reached the stage where food would become a problem, mouse reproductive organs atrophied and ceased to function. On the other hand, when mice were not confined—when they could escape at will to other areas—reproduction continued. Here, as the food shortage approached, excess mice moved out into uninhabited areas and the food shortage failed to materialize. These findings have obvious value in rodent control programs. They are also of importance in building an understanding of population dynamics. Charles D. Louch, working with Emlen and Roland K. Meyer, found that individual mice in dense populations are under a great deal of physiological strain. This, in the light of recent research in the field of physiological stress, might help account for a number of the unusual characteristics of bird and other animal populations in which individuals are packed together or for which only limited food is available.

Research on the function of the pituitary gland has shed considerable light, too, on how the progression of the seasons—fall, winter, spring, and summer—causes variations in the quantity of pituitary hormones secreted. Under the direction of Meyer, Frederick Greeley studied the pituitary function of the pheasant, and James R. Beer that of muskrats. Greeley demonstrated that the springtime increase in pituitary hormone production (sex-stimulating hormones) was followed closely by awakening of the reproductive glands, dormant during winter months. Other scientists had previously noted increased gonadial activity of birds in spring, but Greeley's was the first study in which seasonal variations in pituitary activity was measured directly (by taking weights of pheasant pituitaries at all months of the year) and in which the activity was correlated with sperm production in testes. How day-length influences the pituitary gland is not known, but it is the pituitary, indeed, that triggers reproduction. Beer found that gonadotrophic activity of the pituitary in muskrats, as in pheasants, is highest during spring and early summer. He also found that thyroid and adrenal glands increased activity during summer, and expressed the belief that the springtime urge of muskrats to travel great distances, often across broad land areas, is caused by this increase in hormone activity. Both of these studies have opened the way to further investigations of the processes by which animals summon reserves of energy to surmount reproductive stresses at just the time of year when cumulative hardships of winter are felt the most. Stress is an almost universal phe-

Banding a red-winged blackbird nestling . . . Studies of behavior and migration routes give scientists important hints as to the ways of the wild which can often be translated into practical management measures for game and other wildlife . . .

nomena in the world of life; a better general understanding of stress in animals may very well have implications for man.

Cumulative hardships of winter and added strains of response to pituitary stimulation, plus the stress of crowding or starvation in dense populations, may play a part in one of the most baffling of the biological events affecting certain game birds and fur-bearing animals. Population cycles—the mysterious ups-and-downs to which grouse, rabbit, hare, lynx, fox, and muskrat populations are subject—remain among the most puzzling of natural events. When ruffed grouse are abundant, a census may reveal more than a hundred birds per square mile; when the cycle is at its low point, it may be nearly impossible to find even one. Wildlife cycles are not new. Game populations fluctuated between high and low points long before the white man made note of the fact. Indians and Eskimos well knew that some years are years of abundance, others are years of scarcity, and that cycles of abundance and scarcity follow one another with dependable regularity.

Of the important game species, ruffed grouse are notably affected by cycles, as are, though evidently to a lesser extent, the prairie chicken and sharptailed grouse. In Canada, the snowshoe hare, lynx, and fox are startlingly cyclic. It was at one time generally believed that predation is the cause of these cycles, and that by employing predation principles, it would be possible to arrive at a logical explanation of the hare and lynx cycle. But arguments against this were equally strong. Sunspots and other influences have been invoked as the cause of animal population cycles. However, new evidence has always cast doubt on the validity of each explanation. Among recent theories is one which states simply that cycles reflect periodic changes in weather conditions. Another theory puts forth the possibility that disease and parasite infestations reach epidemic proportions when population densities are at a maximum; whether these are cause or effect is not yet known. Louch's experiments with wild mice populations invoked the explanation that competition between individuals in crowded conditions causes stress that carries many beyond the breaking point and many deaths result. A. W. Schorger has pointed out that "the oldest and commonest explanation offered in Wisconsin for a low ruffed grouse population was a cold, wet spring that caused the sitting bird to abandon its eggs or 'drowned' the young. It is now known that young grouse cannot be reared successfully without insect food. A cold, wet spring that restricts insect activity to the point where few are available results in low survival of the young birds." Projects are now under way to study the role of weather, stress, and disease on cyclic wildlife populations, but it must be said that cycles affecting game species are a subject on which speculation can easily outrun facts.

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"It was quite a surprise to the gold-seeking Spaniards when James Ohio Pattie arrived in their midst, seeking not gold but beavers. Just so is it now a surprise to biological scientists to discover as a fellow-explorer the conservation ecologist, seeking not new ways to squeeze wealth out of the soil, but ways to prevent the extraction of its wealth from destroying its wildlife."
—Aldo Leopold

Chapter Eighteen

MULTIPLE USE

Until recent years, economic development in Wisconsin almost always meant destruction of natural forest and wildlife resources. When forests were cut, they were cut clean, and fire took care of the slash. Birds and other animals that could be eaten were shot in great numbers. For some species, legal restrictions on hunting were invoked too late. It remains an open question, however, whether elk, bison, and other wilderness species could have survived under agricultural conditions even if they had been protected at an early date. The needs of many game birds and mammals are incompatible with agriculture; when grazing areas and nesting sites become grain fields and pasture, these species have no alternative but to vanish. Aldo Leopold took inventory of Wisconsin's game species, and his report was as follows: the State once had seven species of big game (elk, moose, deer, caribou, bison, black bear, wild turkey) of which two remain; 11 species of upland game (quail, prairie chicken, sharptailed grouse, ruffed grouse, spruce hen, cottontail rabbit, snowshoe hare, jackrabbit, two squirrel species, and the passenger pigeon) of which nine remain; and 21 species of breeding waterfowl of which 18 are left. Two upland species have been added: the pheasant and the Hungarian partridge. Leopold pointed out that three yardsticks exist for measuring game wealth: the number of species in the State, the number of species in single localities, and the abundance of individuals of each species.

Decline in game, measured by all three yardsticks, is a reflection of the changes in the land during the past century. We now have techniques to rebuild populations of many of the species that totter on the edge of extirpation in the State. When Wisconsin was undergoing initial stages of development, knowledge of how to avoid unnecessary destruction of resources—or even that it was important to do so—was not at hand. Only now, when much of the native vegetation and some of the wildlife species are gone, have we learned that native plants and animals are often more valuable than cultivated ones, particularly on areas of marginal agricultural value. Native plants and animals are so finely adapted to tapping and conserving nutrients from sparse soil that any change man makes inevitably reduces the land's productivity. Fortunately, in Wisconsin, much of the total area can be turned profitably to cultivated plants and domestic animals. But even in these areas, nitrogen balances are usually in the red, and methods

Ruffed grouse on drumming log . . .

by which nitrogen reserves can be stored in soil and by which favorable nitrogen balances can be maintained are a major problem. Ways must be found to maintain the productivity of good lands, year after year, century after century. Too seldom are nitrogen-fixing and soil-building crops grown. "Man dissipates nitrogen to the sea and air at a far greater rate than he fixes nitrogen chemically from the air," writes Robert H. Burris, a biochemist who conducts research on nitrogen fixation. We remember the history of all the older countries of the world —and a few of the newer. At the end of the "axe, cow, plow cycle," there lies the inevitable depletion of even the richest soil. Spain, Mexico, parts of China, Africa, the Near East—all stand as examples of once-rich, dominant lands for which this story is already an old one. Nature cannot be pushed beyond limits.

How does this apply to Wisconsin? The productivity stored in many soils is prodigious. Decades of cropping fail to render prairie soils bankrupt. But for forest podzols, one or two years of cropping is enough to make it clearly apparent that they must be returned to native species well adapted to them. Even though native plants and animals may not possess the cash value of crops, they are better than nothing at all. And Wisconsin is particularly fortunate in that many of her native species *are* of economic value. We must also remember that the greatest values of forest and wilderness are not always practical values: man is not seeking an abundance of creature comforts alone:

> ". . . on a still night, when the campfire is low and the Pleiades have climbed over the rimrocks, sit quiet and listen for the wolf to howl, and think hard of everything you have seen and tried to understand. Then you may hear it—a vast pulsing harmony —its score inscribed on a thousand hills, its notes the lives and deaths of plants and animals, its rhythms spanning the seconds and the years."

In Wisconsin, the usual history of man pioneering new land has not been carried to its last arid and bitter chapter. Those areas where disaster once threatened most alarmingly, notably the podzol forest soils of the north, have been remarkably reclaimed. Northern barrens have been turned back to crops for which they are by nature intended, trees and wildlife. Wisconsin has been quick to accept the ecological rightness of putting marginal land back into the things to which it is adapted. There now exist in Wisconsin many areas in need of better land management; but it is likely that few have been irretrievably lost.

This did not happen by chance. Many of the areas of the State have been the subject of considerable research, among them the sand plains and marshes of central Wisconsin, the northern barrens and forests, the counties of the Southwest. An encouraging beginning has been made toward good management of resources in the northern and central areas. The Southwest is evidently still in initial stages of development over fairly large areas, although the Coon Valley Demonstration Area has provided a noteworthy exception. One study of 53,965 acres in southern La Crosse County, conducted by Leopold and Joseph J. Hickey, showed that on the area at the time of the study (1941–43) there were 348 farms, of which 44 contained fewer than 30 acres of cropland sufficiently level to be free of erosion problems. Such areas as these might profitably be turned to forest and, incidentally, to wildlife.

The problem of applying the principles of conservation to an entire region is complex even when the principles themselves indicate what should be done. Problems of tax-base and traditional land-use customs create initial difficulties in instituting such programs, even though they will clearly render the land of much greater permanent value. No land policy can be executed overnight. But it can be considered in future planning. It is not a new idea that private, community, and state forests help reduce the danger of regional pauperization, the ultimate end of soil erosion. Game refuges, wildlife sanctuaries, and public hunting grounds are of dual value as protective, productive forests, and as wildlife lands.

There is little need to emphasize that Wisconsin's wildlife is among the State's most valued resources. In recent years, fairly extensive areas have been given over almost entirely to game management. In others, however, as Leonard A. Salter, Jr., pointed out: "The utilization of land for wildlife purposes is very often in serious conflict with the devotion of land to other major uses." This is particularly true in agricultural areas, but it is also true on forest lands. It is important that research to find ways to minimize this conflict be carried on. It is illogical to manage forests for trees alone when deer and grouse can be taken into consideration. But too many deer destroy forest reproduction. What is the proper balance between trees and deer? Deer need openings, and so do grouse. What is the proper balance between forests and openings, taking game into consideration, yet not causing severe economic imbalance? The economics of deer, grouse, quail, pheasants, waterfowl, and all the other game species have not been elucidated.

A sportsman who travels a hundred miles to witness the explosive flush of a ruffed grouse has, in a real sense, put a price tag on his bird. What is it worth to Wisconsin? A hundred board feet of lumber has a price tag; of what value are a hundred ruffed grouse? Forests, deer, and grouse can all be grown together. Erosion control measures in agricultural land can also produce wildlife, forestry, and hunting. We understand the economics of erosion control and forestry; we do not as yet understand the economics of wildlife.

The problem of applying the principles of conservation to an entire region, on a multiple-use basis, when the values of all the commodities produced therein are not known, is an almost hopelessly difficult problem. The day must come when man adopts practices to manage the resources of the earth with intelligence and wisdom. Wisconsin is a pioneer in regional ecology and management. This field of research—combining ecology and economics—holds much assurance that mankind will be able eventually to manage wisely the renewable resources of the earth. Much of the best soil of the earth will probably be turned ultimately to man's direct use in the production of food, fiber, and shelter. Unless that be done intelligently, productive potentials of the best lands will vanish, and in desperation, we will turn to marginal lands for what temporary hope they afford. But used well, the good lands should continue to produce the commodities we need (providing populations do not soar too high), and the marginal lands will

produce trees, wildlife, recreation, and the occasional brush with nature that urban man needs.

A scar on the land violates natural values. It also means resources have been destroyed that future generations—if not we ourselves—will sorely need. The earth has become so thickly populated that man must quickly adopt an ethic going beyond the needs of the living generations.

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PART III

"Far north, far north, are the sources of the great river,
The headwaters, the cold lakes . . ."

—Stephen Vincent Benét

"Is not this possibility . . . of a union of knowledge and beauty one of the most fortunate characteristics of our science?"
—EDWARD A. BIRGE

Chapter Nineteen

EARLY LAKE STUDIES

WISCONSIN'S FORESTED LAND, SOIL, WILDLIFE, LAKES AND STREAMS CONSTITUTE THE State's most valuable native legacy. In one way or another, most of the people of the State are dependent upon these natural resources. It is often pointed out that Wisconsin's many lakes and streams are not only a subject of pride but an economic asset, immeasurable in its total worth. Three-fourths of the State is dotted with lakes that fill basins left by glaciers. Only in the Driftless Area are natural lakes absent. It has been estimated that of the 55,256 square miles in the State, at least one square mile in 35 is water. The total number of lakes has never been determined, largely because of the difficulty of drawing a line between what constitutes a lake and what constitutes a pond. Many small lakes—or ponds—are unnamed. If these small lakelets are taken into consideration, there are, in fact, many more lakes without name than have been accorded that distinction. Generally, however, the census of lakes brings the total number to 8,676. They are concentrated mostly in two groups; one in what has been named the Northern Highland Lake District of northeastern Wisconsin, the second, called the Indian Head Country or the Northwestern Lake District. The former is largely within Vilas and Oneida Counties, the latter in Burnett, Polk, and Washburn Counties. In Vilas County alone, 700 lakes make up 15 per cent of the total area. Forty per cent of the 104,000 acres in the Northern Highland State Forest is water area. In a publication entitled *The University and the Conservation of Wisconsin Waters,* one of a series of bulletins on Wisconsin resources known as the *Science Inquiry Series,* Edward A. Birge, Chancey Juday, and V. W. Meloche wrote in 1936:

> "Not only for recreation, but also for conserving the available supplies of water, are Wisconsin's lakes of incalculable value. In many the outlet is now dammed and the water level regulated, thus allowing the water to be used for power and other purposes, while the others serve as natural storage basins. Consequently, the lakes are of service in staying the flow of water so that man can put it to his own uses, instead of allowing it to rush headlong to the sea with a devastating toll of life and property in the wake of its flood.
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> "As land is used for agriculture, so can water be used for the culture of water plants and animals. The major object of aquiculture is to produce fish, thus supplying food and recreation for man. But while man is chiefly interested in fish, water plants are equally important, since without them fish cannot survive. All species of fish either live on plants directly, or else on smaller fish and animals that depend on plants for their food supply.
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> "Many of the factors that influence the food supply of fish are yet unknown. Wisconsin is fortunate, however, in that it has unsurpassed opportunities for studying these matters, since its abundant lakes vary widely in their physical and chemical characteristics and thus furnish very diverse habits for plant and animal life."

Just as in the history of wildlife, inevitable declines have occurred in what was once a great abundance of fish. Only within recent years have efforts been made

to improve conditions in lakes and streams for natural propagation of fish life. In most areas, this is still possible; in a few, the havoc wrought in the past century is apparently beyond repair.

The Brule River furnishes a fine example of a stream that declined from its original state and which subsequently has been restored to some degree of productivity. This has been accomplished through research and the application of research findings to management. Although a chapter in this volume is devoted to the Brule Survey, it is not out of place to state here that less than a century ago the Brule held the reputation of being a truly fabulous trout stream. In his *True Description of the Lake Superior Country,* John R. St. John, who charted the country for the mining interests, wrote of the Brule as it existed in the early 1840s: "It surpasses all other streams in its brook trout, some of them . . . weighing 10 pounds; its waters colder and clearer, if possible, than any other river." Within 30 years, anglers had discovered the Brule. In 1874, the members of one group filed the barbs from their hooks to save time removing the trout. Three years later, a Superior resident, John Bardon, netted 1,500 pounds of trout through the ice, and in 1878 two men caught 500 by hook and line in three days. By the turn of the century, however, lumbering had sealed the fate of the Brule. Loggers' dams were thrown across the Brule's waters and its watershed was stripped of forest. Spring rains washed down the Brule in a flood, often damaging lodges along the shore. In 1906, an appeal was made to restore the Brule and "prevent for all time the building of dams, and cause the removal of present obstructions, and bring back to its original conditions the fairest river of the northwest." That the Brule would be restored to its original conditions was a vain hope. But that it could be sufficiently repaired to provide a semblance of primeval trout abundance was the result of the survey of the ecology of the entire Brule watershed, begun in 1937 by University and Wisconsin Conservation Department biologists. This survey, and the subsequent restoration of the Brule and other streams in Wisconsin, were built upon a foundation laid by scientists working during the previous half-century.

The first published scientific reports on fish in the State appeared in 1876, and were written by Increase A. Lapham and Dr. P. R. Hoy, whose scientific curiosities were literally boundless. Lapham expressed concern over the depletion of fish in Oconomowoc Lake and the "necessity of some effort for the restoration of the supply of the better kinds." He said the natural supply of fish had been drawn upon by anglers and "the present supply is quite small, compared with what it was a dozen or more years ago." Lapham made as thorough a study of the conditions in this lake—dissolved minerals, temperature, and the fish species to be found—as could be accomplished with equipment available. In a discussion of the practicality of stocking, Hoy described the merits of whitefish, brook trout, "land-locked salmon," black bass, and looked with great hope upon stocking Wisconsin lakes with "that most desirable fish, the carp." Before many years, Lapham's assumption that stocking was a practical answer to the problem of depletion would be proved false and Hoy's expectations for the carp would also fail of fulfillment. Although it was at first a prized food fish, the carp rapidly

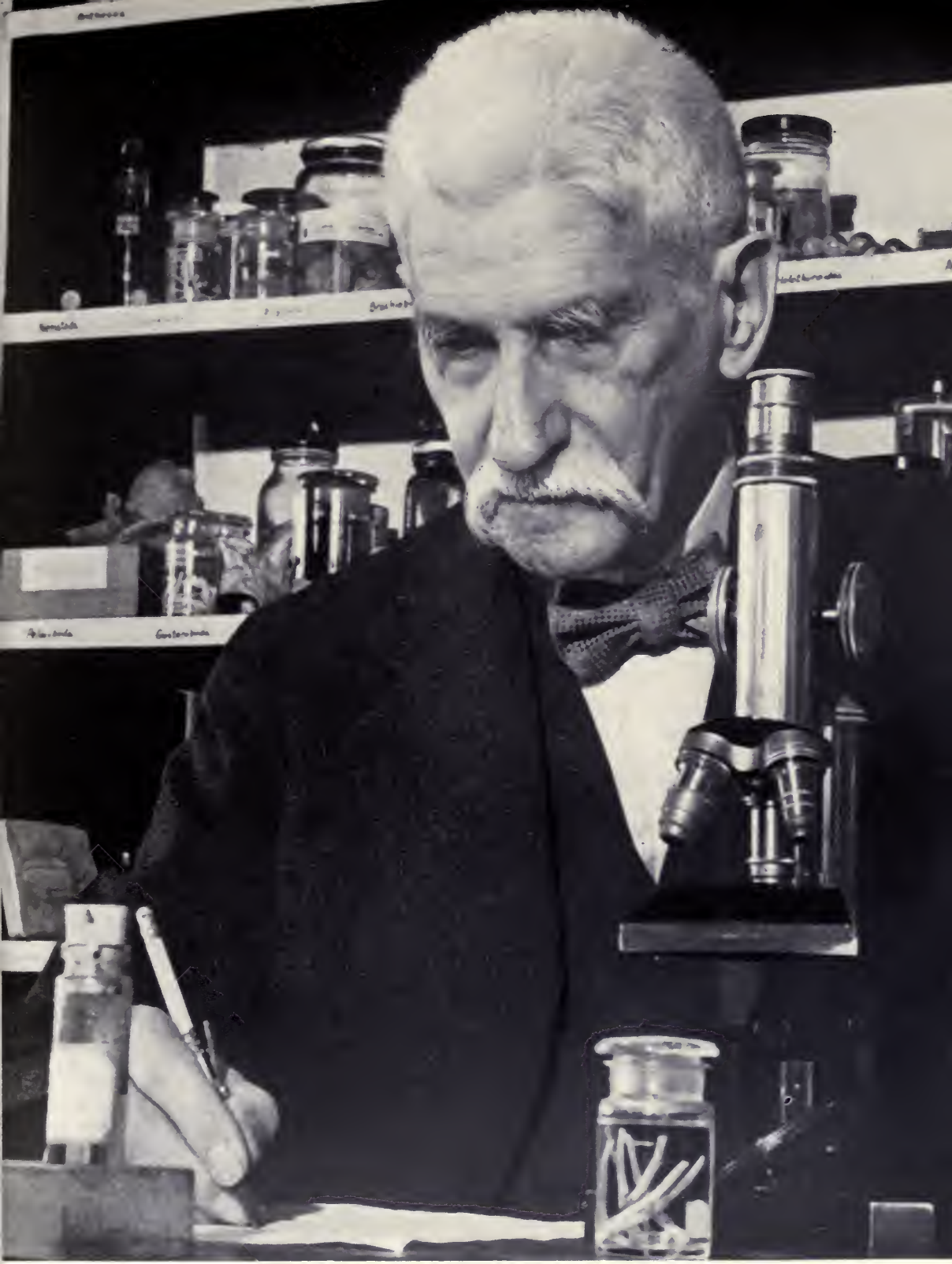
became so abundant in shallow, fertile lakes that it crowded other desirable species out and its general popularity quickly declined.

Shortly before Lapham and Hoy expressed these opinions, a man joined the faculty of the University who was to play a dominant role in developing a new science, a science of lakes and streams and the life therein, to be named limnology. Edward A. Birge made limnology synonymous with the name Wisconsin in the world of science. Birge joined the Wisconsin faculty in 1876, and began his studies of microscopic plants and animals that comprise the basis of the food supply for all higher forms of life in lakes.

The development of limnology at Wisconsin can be attributed to the enthusiasm that Birge, his co-workers, and his successors put into their lake research. It can also be attributed to the fact that the research was started at the microscopic and chemical level. The small aquatic plants and animals, the light conditions, dissolved minerals, temperature, food chains; all of these were studied in great detail by Birge and his colleagues. And, significantly, there were but few studies of the fish in Wisconsin waters until the 1930s. Research during all the previous years had, in a real sense, been laying the basis for subsequent work on fish ecology and management. Once the foundation of basic knowledge had been laid, practical applications were sure to come.

In later years, Birge described his initial research in these terms:

> "No one could have had limnology less in mind than I did when in 1894 I started to work out, by quantitative methods, the annual story of the microcrustacea of Lake Mendota . . . 'fish-food,' to which the young of all game fishes look for nourishment during their early days and on which minnows and other smaller fish feed throughout life. So the fish life of any small lake comes directly from these small crustacea, which in turn live upon the microscopic plants floating with them in the lake waters.
>
> "I meant to make a thorough study, so I selected a primary station about half way out to Picnic Point, where the water is about 60 feet deep. This depth was to be divided into six levels of 10 feet each; the crustacea were to be collected separately from each level, and the different species determined and counted. This process was to be continued for a year or more. In fact, it went on until the end of the year 1897; and included from the several depths nearly 5,000 catches, each containing up to a dozen forms of crustacea, of which eight species were abundant. . .
>
> "In the early days of the study, Mendota surprised me by a revelation of a peculiarity in her life as a lake which was to determine my thinking and my work in science for all the following years. As our crustacea-catching continued into midsummer, we found that our booty began to disappear from the lower waters of the lake. The process continued until the lake became divided into two widely different parts. There was an upper lake, about 30 feet thick, whose water was warm and was filled with abundant plant and animal life. Below this lay an abrupt transition to the lower and colder half of the lake, which was not only cold but also without living plants and animals. . . There is an upper lake which is full of all kinds of fish and which has abundant plant and animal food; and beneath this is a lower lake, dark, cold, and practically without living organisms. It is so far down that it does not receive sunlight enough to operate the machinery of plants, and its waters contain no free oxygen, the breath of life for animals.
>
> "As Mendota cooled in autumn its upper and active stratum gradually became thicker, and the lake reached its full activity at all depths in late October or early November; an activity limited only by the temperature of the water. This process is repeated every year.
>
> "This story, which Mendota told me without my asking for it, was the revelation that sent me into limnology. And the story of Mendota was all the more revealing because



Edward A. Birge, Wisconsin's pioneer limnologist, who opened the world of lakes and streams to scientific study . . .

it is not the ordinary story of an inland lake. The abundant life of Mendota and the gentle slopes of her underwater basin make her an extreme case among the lakes of southern Wisconsin; so for me it was a fortunate chance that put our University on her shores."

The year 1897 also marked the organization of the Wisconsin Geological and Natural History Survey, which sponsored the lake studies as part of its program. Surveying and mapping of the lakes of central and southeastern Wisconsin was carried on in subsequent years by L. S. Smith of the College of Engineering. Victor Lenher worked with Birge, developing methods to measure the amount of dissolved gases in lake waters. Then, in 1905, Chancey Juday joined the survey staff as director of biological work connected with the chemical studies. He later assumed responsibility for both chemical and biological work and directed the lake research program during the period Birge served as president of the University. The list of biologists and University departments taking part in the lake and stream studies is too lengthy to mention here, but at one time or another, scientists from most of the natural science divisions of the University have participated in the limnological research program. Until 1924, the studies were mostly conducted on lakes in the southern half of the State; then in 1925, the Trout Lake Hydrobiology Laboratory was established in Vilas County. Emphasis in the program switched to the lakes of northern Wisconsin, which are basically of a different type than those of the southern portion of the State and present unique problems from the standpoints both of scientific study and resource management. The Natural History Section of the Wisconsin Geological Survey was eliminated from the State budget in the early 1930s and Birge's studies after that time were supported largely by the federal government and the Wisconsin Conservation Department. As the program expanded, its practical aspects became more apparent, but the greatest value of the almost incredible volume of data accumulated by Birge and Juday "may lie in future exploitation," in the words of C. H. Mortimer, a British limnologist, published as this book was in press. Moreover, some of Birge's data even yet remains to be extracted from his notes and published. John C. Neess and William W. Bunge have prepared for publication a summary of Birge's data on the daily temperature, winter and summer, of Lake Mendota for the years 1895–1916, including such additional data as weekly measurements of ice thickness and daily changes in snow depth, light penetration, and other conditions. The information on ice thickness has been found of great value in meteorological studies of cycles in weather. Who knows what other uses this great volume of material will have in future scientific studies? However useful it may be to future generations, much of the information on Wisconsin lakes revealed by Birge and his co-workers was translated almost immediately into practical applications. In 1936, the following statement summarizing the lakes research program was issued:

"Most of Wisconsin's inland lakes are too small to be exploited successfully for commercial fishing, but they are highly valued for sport fishing. It is estimated that 85 per cent of the tourists who visit our lakes spend some time in fishing. Hence, fish production must be kept at a maximum in order to satisfy the demand for this type of recreation. One fundamental approach is to investigate what types of material fish live on . . . How much fish food is present. . . Whether the quantity of fish food can be increased. . . Rate of growth of various species of fish in different types of water. . .

The balance between the fish population of a lake and the plants and animals that make up the potential food supply. . . Why certain species of fish cannot be propagated in some lakes . . ."

Each of these questions had to be answered by separate projects within the lake studies program, but together they have provided a fund of fact and philosophy that is without rival. Aquatic resources of few other regions of the world have been so thoroughly studied and as well understood. In no other area has the application of management measures been established on so solid a foundation of basic knowledge. In recognition of Wisconsin's leadership in this field, and of the pioneer work of Birge and Juday, the University of Wisconsin served as host in 1940 to the first symposium on hydrobiology ever to be held. A score or so of the nation's leading ecologists participated in the scientific program, and 300 scientists from all parts of the nation attended. At a dinner commemorating his 86th birthday (he lived to be 98) Birge expressed gratitude that limnology, as a science, still possessed the charm and the limitations that characterize beginnings. Birge said:

" 'We know in part' has been our real text, however long the words of the titles on our printed program; and when we told our stories, our telling was also 'in part.' Will these bits of knowledge, expressed in words as fragmentary, come together into a well-wrought frame of life? Or shall we, like a greater than Marlowe, still hesitate between 'untraceable' and 'unfathomable' as Mendota and her sisters try to tell us of the uncounted wealth of revelations yet to come; while we can feel little more than the limitations of our own powers of possession?"

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"What barriers have been cast across the courses of our rivers, and how they have been removed by the action of water and drift in the long periods of the past; what immense tracts were once covered with water, forming fresh water lakes where now men plow, hoe, and tend crops, and human habitations stand."

—J. G. Knapp (1872)

Chapter Twenty

LAND, WATER, AND CHEMISTRY

The barriers of which J. G. Knapp wrote in 1872 were those that dammed the water in Wisconsin's glacial lakes. Lake Duluth lay in Douglas, Bayfield, Ashland, and Iron Counties. Glacial Lake Wisconsin extended through Adams, Juneau and north into Wood County. Glacial Lake Oshkosh occupied large areas in Marquette, Green Lake, Winnebago, Waupaca, and Outagamie Counties. These latter two lakes were formed behind natural dams of stone and gravel dropped as the lobes of the glacier retreated northward from the State. Eventually, the lakes filled and water began to flow over the natural dams, wearing away the material of which the dams were composed. Lake Duluth's history, and even its extent, are not yet explained to the full satisfaction of all glacial geologists, but it is known that Lake Wisconsin drained when a moraine that dammed the Wisconsin River was worn away, leaving a gorge through rock at the Wisconsin Dells. Lake Oshkosh was formed as the Green Bay lobe of the glacier melted, and this lake, too, drained through the Wisconsin River.

How the lakes and ponds of northern Wisconsin were left in the wake of the retreating ice shield has been described by Fredrik T. Thwaites:

> "In hollows, valleys, and depressions between drumlins, masses of stagnant ice from a few feet to two or three miles in width survived just as isolated bodies of troops are left behind during the retreat of a defeated army. Protected only by a mantle of melted-out drift accumulated from their own burden, these would soon have succumbed to the sun's rays; but . . . vast quantities of water flowed from the glacier and buried these isolated blocks in sand and gravel with scattered boulders carried by icebergs. . . Kettles formed when the isolated ice masses which were buried in the till melted; into those kettles which formed before the surrounding moraine was clad with vegetation, red clay, fine sand, and some ice-rafted boulders were washed."

Kettles or hollows in the landscape were formed when the huge ice chunks melted. Today these hollows, filled with water, remain and constitute the kettle lakes of Wisconsin. Only one area of the State—the Southwest—was untouched by the glaciers, and the absence of lakes and of drift (sand and gravel left by the glacier) stands as evidence of this. With the exception of the southwestern counties, Wisconsin was actually glaciated at least four times, according to evidence so far gleaned by geologists, but the last glacier was the one to leave the most obvious marks on the Wisconsin landscape.

Important, from a practical standpoint today, is the fact that the northern lakes differ from one another in character. All were formed at the same time. Why

The post-glacial geology of Wisconsin, showing the beds of the ancient lakes (dotted areas) and the Driftless Area. The Wisconsin Drift is the area of last glaciation. (Map prepared by Fredrik T. Thwaites.)

should they differ? The answer to their variation lies in the fact that some are connected by streams, some are not. As Birge described them:

> "The great majority of these little ice-block lakes connect with the system of streams, as do Trout Lake, Plum Lake, Star Lake, and hundreds of others. But there are also lakes like Crystal, Weber, Diamond, and many more, which have no relations with streams, no inflow and no outflow, whose only connection with the outside world is by way of the air or underground. These are the *seepage lakes,* each one of them an individual, more completely isolated from the rest of the world than is any other small area of the earth's surface. They show their isolation by their peculiarities; their water is soft, their stock of plant and animal life is limited both in quantity and variety, as compared with that of drainage lakes. Thus they offer to the limnologist extreme cases for study, extreme in their chemistry, their physics, and their biology. . . Thus Wisconsin has given us here a lake district that is unique in the world. The seepage lakes constitute a high point of its nature; each of them is a sort of tiny water-cosmos by itself, yet each of them has a life-history that fits into that of the community of lakes and of the lake district.
>
> "Our knowledge of the story of these lakes is still in its beginning—if, indeed, *beginning* is not too ambitious a word for the little that we know. But though it is small, we know enough to be sure that our seepage lakes and the Northeastern Lake District, of which they are members, have still large contributions to make to our youthful science of limnology."

The unanswered questions still are many, but the basic chemical differences between seepage and drainage lakes were revealed by Birge, Juday, and chemists who worked with them, notably V. W. Meloche. These differences were reported in a long series of scientific papers, beginning with the first, written by Birge in 1906, "The Oxygen Dissolved in the Waters of Wisconsin Lakes," and culminating in the "Mineral Content of the Lake Waters of Northeastern Wisconsin," written in 1938 by Juday, Birge, and Meloche, and "Physical and Chemical Evidence Relating to the Lake Basin Seal in Certain Areas of the Trout Lake Region of Wisconsin," written in 1943 by Juday and Meloche.

In the latter paper, Juday and Meloche offer an explanation of why seepage lakes seem to be "completely isolated from the rest of the world." For one thing, these lakes are not connected by streams or rivers to broad watersheds. In addition, for some as yet unknown chemical reason, they are literally sealed off from soil beneath and ground water around them. This lake basin seal is effectively watertight. It even prevents lake water from draining from seepage lakes through subterranean sand to lower neighboring lakes. Unless the watershed of these seepage lakes contains limestone concretions (and some do) their mineral deficiencies render them comparatively void of living things, while lakes not a quarter of a mile away, and fed by streams or larger watersheds, are often abundant with fish life. The water entering seepage lakes comes largely from rainfall or snow. They are sealed off from all possible sources of minerals. Consequently, the water in them is extremely low in silica, iron, manganese, calcium, magnesium, nitrogen, and other elements vital to plant life and, ultimately, to animals. What this means in the life of these lakes is simple:

> "In the very soft water lakes of northern Wisconsin the mineral content is low—so low, in fact, that even the commoner substances, such as calcium and magnesium, are scarce. As a result of this mineral shortage certain types of plants and animals do not thrive in these waters. The species of large water plants found under such conditions are few in number and for the most part different from those growing in harder waters. Mollusks, such as snails and clams, are also scarce . . ."

In a sense, these lakes are barrens—they are barren of the chemical fertilizers that make an abundance of living things possible. And they contrast sharply with the drainage lakes around them, which obtain essential minerals and dissolved gases from watersheds and networks of streams that flow into them. They also contrast sharply with those lakes of southern Wisconsin in which an incredible quantity of minerals, draining into each lake from adjacent farmlands, leads to such profusion of plant growth during summer that the lakes may become a temporary nuisance to human lakeshore residents. Here was at least part of the answer to a question Birge and Juday asked as early as 1911: "Why do different lakes differ so widely in productivity or ability to support plankton?" Plankton—the almost microscopic plants and animals that constitute food for the smallest fish—exist in proportion to the minerals present in lake water. And the fish production of a lake is, in general, proportional to its yield of plankton. Extremely small in size, plankton organisms are present in such tremendous numbers that they far outweigh all fish, insects, worms, and mollusks inhabiting a lake and its shoreline. Plankton are a basic link in the food chain.

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Plankton is collected in special nets towed behind a boat, then transferred to bottles for identification in the laboratory. . . . The productivity of a lake, as far as fish are concerned, is directly dependent upon its productivity of plankton.

"A lake is a landscape's most beautiful and expressive feature. It is earth's eye, on looking into which the beholder measures the depths of his own nature."

—HENRY THOREAU *(Walden)*

Chapter Twenty One

PLANKTON, STAFF OF LIFE

IN THE EARLY DAYS OF HIS STUDY OF THE MICROSCOPIC PLANTS AND ANIMALS THAT inhabit Lake Mendota, Birge came upon a puzzling fact. In his collecting, he had taken pains to obtain samples of plankton organisms, as they are known, from all depths of the lake. In early spring and summer, he found them equally abundant in deep waters and near the surface, but as summer wore on, plankton disappeared from the lower depths, despite the fact they continued to grow abundantly near the surface. When Birge dropped a thermometer on a line, he found another striking fact. As the thermometer went lower and lower, it did not show a uniform temperature drop. There was, instead, a warm upper layer of water some 30 feet thick, then a region of sharp temperature decline, perhaps 15 feet in thickness, and then finally a cold layer of water, nearly uniform in its temperature, that extended all the way to the bottom. Why should the lake be divided into layers?

The answer to this was to be found in the annual cycle of warming and cooling brought about by seasonal differences in sunlight, wind, and weather. And its implications were profound—it explained not only why plankton is absent from the depths of Wisconsin lakes during mid-summer when, with all logic, it should be abundant but also why fish are not to be found there.

First of all, Birge reasoned, during summer the upper layer of lake water becomes warmed in the sun, while lower depths remain dark and cool. There is a time each spring, however, in which no such stratification exists, and all the waters of the lake are nearly the same temperature—about 40°F. When this is the case. the lake "turns over" freely; prevailing winds continually push the upper layer of water to leeward and pull to the surface the water that has been near the lake bottom. But as the spring sun warms the surface, the water here becomes lighter. It acts like a layer of oil and will not mix with the lower, heavier water layer. This seals the cool lake depths away from contact with air. Birge saw what this meant. In spring and fall—when the water of the lake can circulate freely—water at all depths has plenty of oxygen. But after the lower strata have been sealed off for a time, the oxygen is used up. Toward the middle of summer. lower depths become devoid of oxygen; in late winter these depths have less oxygen than in fall.

What does this mean in terms of plankton growth? Birge believed it meant that lake waters have an opportunity twice a year to take up oxygen from the air

and carry it to the depths where it can support life. There are a few anaerobic forms of life that can get along without dissolved oxygen, but they are relatively insignificant. Following the spring turn-over, oxygen in the lake depths is used up in a month or two, and by midsummer the living things in deep water must move upward into regions containing dissolved air. In the brighter surface layer, too, green algae can grow, and algae supplies additional oxygen to lake water through its process of photosynthesis. These things explained why Birge could find no plankton at the lower depths during late summer.

There are two major forms of plankton—the green plant plankton or phytoplankton and the animal forms of plankton or zooplankton, which include small worms, insect larvae, and free-swimming crustaceans. Like green terrestrial plants, phytoplankton or algae manufacture starch and proteins from sunlight, carbon dioxide, minerals, and water. The zooplankton organisms feed on living and dead phytoplankton and bacteria. The smallest fish feed on the zooplankton. And so the cycle begins. It ends, finally, with the consumption of minnows, perch, and other small fish by the largest fish in the lake—bass, pike, and muskellunge. In a very real sense, everything depends upon the first link in the chain—phytoplankton and photosynthesis.

Although plankton organisms are so small as to be near the limit of visibility to the unaided eye, they are often so numerous in the waters of lakes that, by weight per acre, they rival the most productive farm crops. In the early lake research, Wisconsin scientists strained plankton organisms from some 4,750,000 pounds of water (about 2,000,000 quarts). From the plankton thus obtained, it was possible to calculate that the portion of Lake Mendota with water more than 65 feet deep contains a standing crop of more than 3,800 pounds per acre, or nearly two tons of fresh material. The yields were found to be smallest in February, with about 2,300 pounds per acre, and largest in December, with about 4,500 pounds per acre.

One of the most striking facts brought out by research was the difference in plankton productivity between lakes of northern and southern Wisconsin. Juday compared two northern lakes—Weber and Nebish—with Lake Mendota and Green Lake. This is what he found:

	Phyto-plankton	Zoo-plankton	Bottom Plants	Animals	Fish	Dissolved Organic
Weber Lake	583*	41	366	73	38	2,663
Nebish Lake	608	42	590	122	35	3,829
Green Lake	2,767	177	4,218	138**	Unknown	27,901
Lake Mendota	1,995	120	4,600	414	Unknown	15,201

* Weight of material in kilograms per hectare of lake surface.

** Few animals at the very bottom of Green Lake because of its extreme depth.

It can be seen that Weber and Nebish lakes never attain the productivity of the two southern lakes to which they are compared. Juday reported that the plant crop in the two southern hard-water lakes weighed three to five times as much as that in the same area of soft-water lakes. Soft waters have only a fourth as

A photograph of three of the more abundant types of zooplankton; a *Daphnia* at the left, *Diaptomus* in the center (the lower with a cluster of eggs in an egg-sac) and a *Cyclops* at the right (with two egg sacs). Each of these animals is about the size of a dot . . .

many species of large aquatic plants. The animal population, even excluding fish, weighs two to three times as much in hard-water lakes.

Regarding the work on lake productivity, Birge and Juday summarized:

> "While the plankton organisms are minute in size, they are present in such great numbers that they contribute a larger amount of organic matter to the waters of a lake than any other type of plant or animal life. Studies have shown that the average standing crop ranges from a minimum of 45 pounds of dry organic matter per acre in the very soft water lakes to a maximum of 214 pounds per acre in Lake Mendota. Two of the animal forms, the rotifers and crustacea, contribute from six to 10 per cent of this material, and the greater part of the remainder consists of algae.
>
> "It is impossible to state accurately the annual yield of plankton, but it doubtless is huge, since it has been estimated that the crop is renewed every two weeks. Assuming conservatively that the renewal takes place 20 times a year, the annual production ranges from 900 pounds of dry organic matter per acre in the plankton-poor lakes to 4,300 pounds per acre in the plankton-rich waters. It should be borne in mind that this is on a dry-matter basis; the annual crop of plankton as found in the lakes would be about 10 times as large, since 90 per cent or more of the living material consists of water."

Birth and growth are not the only processes in lake life that need to be understood. Death and decay are processes by which living things pass on to new generations the chemicals of which they are composed. A *Daphnia*, for example,

that has accomplished what is, for it, the ultimate goal of life—reproduction—will eventually die and its substance will settle to the lake bottom, to be added to the accumulated corpses of countless other plankton organisms. Here another great group of living things—bacteria—carry on a life-cycle of their own. In the process of feeding on organic sediments, they release chemicals which will be taken up by living algae to begin anew the cycle of nutrients, energy, and life. While it may seem from the accumulated data that the story of what happens in the life cycle of an inland lake must be nearly complete, such a conclusion is not justified. We have only begun to learn, for example, what dissolved minerals are needed for abundant growth of plankton, what species of phyto-

Collecting plankton from the waters of a northern experimental lake . . .

plankton are most productive of food for crustaceans upon which fish feed directly, and what the limiting factors are in lakes low in productivity. The questions to be asked are many. What are the cycles through which lake chemicals revolve during the transformations of birth, life, death, and decay? What determines whether a molecule of nitrogen or phosphorus shall be available to living things or be tied indissolubly to other elements in the lake bottom, waiting for who knows what event to be once again taken up by the cycle of life? These

and other questions must be answered before Wisconsin's lakes can be completely comprehended, and before they can realize the productivity of which they are potentially capable.

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Nets must be taken in and the fish counted at the end of each time interval, no matter what turn the weather may have taken . . .

"Since the natural metabolism of lakes is fairly well known over large sections of the globe, descriptive limnology has reached sufficient maturity to permit experimentation on the economy of lakes. . . Progress in aquiculture is 50–100 years behind agriculture, yet the latter has long since found that research pays dividends. . . The invisible depths yield their secrets stubbornly."

—ARTHUR D. HASLER

Chapter Twenty Two

THE ULTIMATE GOAL—FISH

NATURE'S ULTIMATE GOAL IN THE PYRAMID OF NUMBERS IS FISH, AT LEAST AS FAR as life in northern Wisconsin lakes is concerned. The goal of much of the lake research at the University has been improvement of quality and increase in numbers of game fish produced by Wisconsin lakes. Just as improved cattle production involves the pasture upon which cattle feed, so does lake research involve the plankton upon which fish feed. Research, above all, has brought out a first principle for successful and economical management of lake and stream resources:

> "One point that needs to be emphasized is that artificial stocking of lakes and streams with fish does not necessarily insure an abundant supply. Our waters can only produce as many fish as they can feed. Consequently, increasing the fish population of a lake beyond the limits of its food supply only results in failure, or in production of a large number of undersized fish. These considerations point to the need for study of the environmental conditions in lakes to determine their fish-carrying capacity. Such a procedure furnishes a sound basis for restocking lakes with the most desirable numbers and species."

The work of Edward A. Birge and Chancey Juday and the other early lake researchers formed the basis for a fairly comprehensive understanding of what makes a lake behave as it does. When they had finished, it was known, for example, that the waters of most Wisconsin lakes "turn over" twice a year. It was known why oxygen is deficient in lake depths at certain times. It was known that plankton organisms constitute an enormous annual crop of living material, and that the quantity of plankton depends directly upon the quantity of minerals dissolved in lake water. It was known that zooplankton which feed the fish—largely the forms named *Daphnia*, *Cyclops*, *Diaptomus*, and the *Rotifers*—feed in turn upon phytoplankton, and that the latter thus constitute the base of the food chain. An increase in phytoplankton, theoretically, will result in an increase in fish. With the exception of bog or other small lakes in which chemical treatment sometimes almost works a miracle, fertilization of northern Wisconsin lakes to improve their productivity of fish, however, has never been notably successful.

The chemistry of a lake is fully as complex as the chemistry of soil, and the conditions imposed by lakes make research difficult. At the present time, however, a good deal of information has been amassed on the chemistry of plant growth in lakes, but some of the crucial facts are not yet in. Which mineral nutrients are in such short supply that they limit the growth of phytoplankton?

This little lake differs from all its kind—it alone is radioactive. Tagged atoms are being used to check the processes by which plants obtain nutrients.

How can lake chemistry be managed to increase productivity? Might lakes be fertilized successfully? In cooperation with Wilhelm G. Einsele, an Austrian limnologist known for his research on fish production in European ponds, Arthur D. Hasler writes:

> "Tampering with a lake's economy can have its good or bad effects. Economically, we must take the view that any effect, in the last analysis, should be toward an increase in the fish crop. To do this, a rise in fish food production must be realized which is not always easy to obtain. A lake . . . is an extremely complicated environment; not without reason it has been called a 'highly developed organism.'
>
> "Lake fertilization fundamentally is widely different from land fertilization; many principles from the latter do not carry over. To increase the plant biomass is the goal of fertilization. It is in our hands to multiply the algae which initiate the food chain to fish. For example, in a natural lake, a rich growth of *Cyclotella,* a small diatom, fulfills the ideal food requirements of *Daphnia,* but fertilization might encourage previously rare or non-existent algae which are not adapted at all well as food for *Daphnia,* while the desirable form, *Cyclotella,* is suppressed. Our knowledge has not progressed to the point where we can direct the succession of algae so we must be content, at present, to work out the essential economy of biomass production in a lake."

Increasing the number of fish by artificial fertilization of lakes, thus, must await the acquisition of more complete knowledge of lake ecology. But the problem of increasing the quality of fish in lakes is one for which some answers are already at hand. Matters of oxygen supply and food, water depth, and nearly countless other factors help determine whether a lake is a "trout" lake, a "bass" or a "muskie" lake. But some lakes produce larger fish than others containing the same fish species. Why should this be so? The answer evidently lies in the density of fish populations. Once again, it was Lake Mendota that provided a clue to the answer.

There are few lakes in this country for which old, well-authenticated, and detailed records exist of angling success, but there are records for Lake Mendota going back more than 50 years. In 1947, John Bardach and Hasler began a study of the history of Lake Mendota to learn whether an explanation might exist for the unusual fact that Mendota's perch come in literally "jumbo" sizes. Moreover, Mendota is one of the best perch lakes in the world from the point of view of angler success. Summer and winter for many years, scores of fishermen have caught the legal limit—25 perch—day after day. The bag limit was removed entirely in 1955. Although the size of this catch might be considered remarkable by itself, the records show even more phenomenal catches in the past. At the turn of the century, a single commercial fisherman sometimes obtained over 800 perch a day. Two scientists, A. S. Pearse and Henrietta Achtenberg, wrote in 1916 that "the usual catch of a professional fisherman, fishing through the ice with a line and two hooks, is from 200 to 400 perch per day." They made an estimate, based on food believed to be available in the lake and daily food consumption by perch in aquariums, that 15,000,000 perch inhabited Lake Mendota. The decline in numbers of perch, from 1916 to the year in which Bardach began his study, was believed to have been the result of a disease epidemic that killed millions of perch annually. Scientists first found indications of disease in 1884. Disposal crews hauled 200 tons of dead perch from Madison shorelines that year.

Although such mass die-offs have not occurred in recent years, the perch continue to be infected by a parasitic disease (harmless to man) that evidently attacks older members of the perch population.

Over the years, another change has taken place in the perch population. In 1916, there were 10 perch to a pound. In 1931, four average perch weighed a pound. In 1946, three tipped the scale. This change has taken place despite the fact that no important changes in food available to perch have been detected over the years. And as Bardach pointed out, if perch populations were declining, "the same amount of food would be present for utilization by increasingly fewer and younger perch. . . And it is known that young fish utilize their food more effectively than old ones." This would account for the increase in the size of individual perch, while the total number of perch in the lake declined.

Calculations made in 1948 showed some 2,000,000 to 4,000,000 perch to be present in Lake Mendota, but a recent creel census indicated that an upward revision of this estimate will be necessary. A census of ice fishermen conducted in the winter of 1956 by Warren J. Wisby gave an estimated catch of 1,196,800 perch between December 21 and March 24. The perch averaged over 8.8 inches in length and weighed one-third of a pound, a yield of 41 pounds per acre for this three-month period alone. The Wisconsin scientists are emphatic that these figures represent only the best estimate to date—there will undoubtedly be revisions as the study continues and more accurate estimates become available. Hasler states:

> "If one assumes 15 pounds per acre as a conservative yield of fish in Wisconsin waters, the estimated million acres of inland water in Wisconsin should permit a minimum harvest of 15,000,000 pounds of fish, or about four pounds of fish per person per year in the State; double this quantity would probably be more nearly the figure we should use. It is inconceivable that this quantity of fish is removed by angling. . . While there is some evidence that over-fishing is possible for large predator fishes like trout, bass, northern pike, walleye, muskellunge, there is no evidence up to this time that panfish angling has been harmed by intensive fishing, even in relatively unproductive lakes in northern Wisconsin. . .
>
> "In the past 100 years, the greatest changes in our fish populations have been with quality rather than quantity. Quality has been altered drastically as has the species composition of many aquatic habitats. In some areas, moreover, over-fishing of large predator fishes has materially changed the size composition. Pollution, construction of impoundments, and soil erosion have modified aquatic environments so that streams no longer lend vigor to native sport fishes in their former numbers and ratios. For example, denuding of the natural cover from our watersheds has spelled doom to the native brook trout in most southern Wisconsin streams. As a result, other species which tolerate modern stream conditions have taken their place. To repeat, it is not unlikely that such a habitat still produces as many pounds of fish meat per stream mile as before —it consists only of different species, not so desirable."

The difficulties of lake and stream research are multiplied by the fact, simple and unpoetic, that everything important happens under water. This makes observation and study extremely difficult, sometimes hazardous. It is still not possible to count the number of fish in a lake or stream, and even methods of estimation are inaccurate. Biologists, for these reasons, have yet to learn many elementary facts of fish ecology. Does size of the hatch influence the growth rate of individuals? With fewer adult spawners, do hatched fry grow into adult fish more

rapidly? What are major causes of death for young fish? An adult bass will lay more than 5,000 eggs; why do only a very few survive and grow into adult fish? At what age are newly-hatched fish most in danger from predators, from food and oxygen shortages? What species compete for food, oxygen, and living space? What diseases affect fish? How can food be increased? Only a percentage of the fish artificially stocked are ever recovered by anglers; what happens to the remainder? Will gamefish, such as bass, walleyes, and muskellunge, grow to good sizes in lakes where unlimited panfishing is permitted? It seems that stocking trout is essential if sufficient trout to satisfy angler-demand are to be had in Wisconsin streams; what are some of the best and most economical ways to grow them? These are questions yet to be answered.

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Bass are captured, tagged, and released at a distant point to determine whether a large proportion will return to "home" territory, and how long it will take them . . .

"There are many unsolved riddles in Nature, not the least of which is the migration of fishes."

—Ludwig Scheuring

Chapter Twenty Three

THE GREAT MIGRATION MYSTERY

The mysteries of migration in both birds and fish have long confounded biologists. How some animal species navigate unerringly over thousands of miles of land or water to some pinpoint on the map is a riddle for which there has been no easy answer. One of the most spectacular aquatic migrations is the annual journey of salmon from the depths of the sea to the headwaters of mountain streams. Salmon swim hundreds of miles, make many correct decisions at stream forks, and find the rivulet in which they hatched some four years earlier. Migrations of other species are on a smaller scale, but are none the less baffling. The rainbow trout of the Brule River and other streams entering Lake Superior and Lake Michigan make annual migrations to and from Great Lakes waters. The sea lamprey, cause of tremendous losses to commercial fishermen, migrates into rivers and streams at spawning time. During winter months, game fish seek the depths of lakes and rivers, then return to more shallow levels in summer. At least one species—the perch—has been found to make daily migrations to and from shallow water.

The subject of migration is of more than academic interest. Important as an understanding of migration might be to fill a blank spot in our knowledge of animal behavior, many aspects of migration are of practical importance to biologists who attempt to achieve maximum productivity from lakes and streams and to fishermen who patiently match wits with nature. The electric weir, we hope, will spell doom to the sea lamprey while permitting safe passage for rainbow trout on spawning migrations. Lake and stream improvement measures must take into account the instinct for migration. For biologists making fish censuses, it is important to know whether the fish they are counting move around a great deal or whether they remain within restricted areas around nets or traps.

Research into the mysteries of fish migration began at Wisconsin about 1946. In that year, a basic research project was conducted to learn whether the sense of smell played an important part—or any part at all—in the life of a bluntnose minnow. It was known, in a general way, that at least some fish species have an acute sense of smell. Sharks and tuna, for example, can be drawn to a fishing boat by bait thrown into the water. A German scientist, Karl von Frisch, had already noticed that odors from injured skin of one fish frightened other fish of a school; this, very likely, served to warn them of a predator attack on the school even though they had not witnessed it. Another scientist had found that bullheads have epidermal taste buds distributed from head to tail.

At Wisconsin, Arthur D. Hasler and Warren J. Wisby found that bluntnose minnows do, indeed, have an extremely sensitive sense of smell. Trained minnows responded to enormously diluted chemicals in the water around them. To learn whether bluntnose minnows can smell the difference between two different streams, Hasler and Wisby attempted to train them to react differently to water from Otter Creek and Honey Creek—two similar streams located not five miles apart in Sauk County. The experiment was a success—and its implications for helping to explain how salmon navigate became apparent. With a grant from the U.S. Office of Naval Research, the Wisconsin scientists moved their experiments to the West Coast. They caught migrating salmon that had been tagged—whose home streams, therefore, were known—and plugged the noses of these fish with absorbent cotton. The salmon with plugged noses promptly committed what, for salmon, is an uncommon error. They became lost, while migration mates with unplugged noses continued along correct routes to spawning grounds. The experiment showed that salmon literally smell their way from the sea back to home tributaries. There are practical possibilities for this discovery. Great dams now block many western rivers; these dams have seriously reduced salmon spawning success. Hasler and Wisby point out that dam-blocked streams might be given an artificial smell (certain organic chemicals should be effective) while salmon are hatching and migrating seaward. Then, four years later when they are returning to spawn, they might be decoyed into foster streams by moving the chemical signpost.

The fact that salmon employ the sense of smell to navigate upstream does not solve the entire mystery. During four years at sea, salmon swim hundreds of miles from the spot where home streams enter the ocean. Though they are capable of recognizing home stream water in great dilution, it seems incredible that they could discern it over distances that salmon are known to travel at sea. Working with minnows, Hasler has gathered evidence to show that the sun serves as a guide for aquatic as well as terrestrial navigation, and experiments are now being conducted to prove this contention. Birds use the sun for navigation (see Chapter Fifteen) and fish may do the same. Wisby has found that green sunfish and black bass, taken from accustomed surroundings and returned to the lake at a distant spot, will quickly return to the area from which they were taken. The effect of this remarkable homing trait is being studied and its influence on census methods and population estimates is being worked out.

Migration is not inevitably as spectacular or as long-range as the salmon's return from the sea. Using a U.S. Navy launch fitted with echo-sounding gear or sonar, the Wisconsin researchers have found that Lake Mendota perch conduct both annual and daily migrations. In 1952, a project sponsored by the Office of Naval Research was begun and the *Impulse* began a long series of cruises back and forth along established routes in Lake Mendota. James J. Tibbles, Hasler, electronics engineer James R. Villemonte, and a number of research assistants followed and charted the movements of perch schools for as long as 48 hours at a stretch. The work of adapting sonar to shallow, fresh-water lakes will have

applications of value to marine engineers; it shows considerable promise of becoming a useful tool for fresh water biologists.

Using the *Impulse's* sonar, the scientists were able to locate the areas of greatest perch concentration in Lake Mendota at all times of the year. With sonar, aqua-lung diving, and gill-netting, they have been able to observe some interesting perch habits. During winter, perch are in the great depths of the lake. As spring arrives, they begin to disperse upwards, and by April they are evenly distributed from top to bottom. Toward the end of April, they work into the shallows to breed, and having bred, move once again into deeper water. This time they seek not the great depths (Lake Mendota is 84 feet at its deepest) but a level about 35–55 feet deep. During the remainder of summer, the perch tend to congregate as deep as the oxygen supply will allow. They rise to a stratum around 22 feet during hot weeks of July and August, then sink again as days become cooler. The Wisconsin scientists also found that perch in one area of Lake Mendota swim to a gently sloping underwater shelf at dusk and come to rest on the lake bottom, where they remain throughout the night. Perch schools not located near a convenient shelf, however, remain suspended at their usual depth throughout the night. What biological significance this nightly migration might have is still not known.

These experiments, in laboratory and lake, have begun to raise the curtain on one of nature's most mysterious worlds. Wisconsin is wonderfully endowed with the raw material for limnological research. The State is dotted with fresh water lakes. The University campus borders one of the nation's most productive and interesting of these lakes. With echo-sounding, aqua-lung diving, and other new techniques being developed to study aquatic life, the panorama of events beneath the surface of Wisconsin's lakes has begun to give way to scientific understanding.

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A bog lake is limed to convert it to a lake suitable for growing rainbow trout.

"Under good management, the total fish population, and thus the total yield, will be so controlled that the productive capacity of the water will be utilized to the fullest extent possible for the production of those species most desired for economic and recreational purposes."

—C. M. Tarzwell

Chapter Twenty Four

SMALL LAKES FOR TROUT

One of the finest instances in which research has turned a hitherto economically useless part of Wisconsin's landscape into a productive one is provided by the work of Wisconsin Hydrobiology Laboratory scientists on the State's bog lakes. Northern Wisconsin (and for that matter the entire glaciated region surrounding the Great Lakes) is dotted with these relics of the age of ice. Just as larger lake basins were formed when huge, buried pieces of glacial ice melted, so were bog lakes formed by less imposing ice chunks that left smaller holes in the landscape when they melted. Many bog lakes contain fewer than 15 or 20 acres of water surface. They are surrounded by marsh and are filled with dark, tea-colored water. The source of the coloring material is to be found in the surrounding marsh. Here rainwater picks up soluble or colloidal organic material from decaying peat and carries it into the lake. Plant life is unable to grow in any profusion in bog lakes because the dark water effectively prevents sunlight from penetrating to depths beyond a very few feet. Typical fish life of a bog lake is an occasional bullhead or a stunted panfish. In 1945, Wisconsin scientists began a series of experiments to learn why bog lakes were unproductive of fish and to devise methods by which bog lakes could be improved as fishing waters.

In preliminary studies of northern bog lakes, Arthur D. Hasler and scientists working with him reasoned that any method of treating these lakes to free the water of its brown color would increase productivity of fish by increasing the depth of light penetration, hence permitting heavier growth of plankton organisms. This would also result in better oxygen supplies at lower levels in the lake as a result of photosynthesis by algae. These changes would not have a great influence on panfish and bass populations because such species can tolerate the warm water at the surface of bog lakes. But there were, as early as 1946, indications that treated lakes might furnish oxygen supplies sufficient for trout at the cool, lower strata in addition to providing food more suited to trout than to other fish species.

The reason bog lakes might produce better trout food than food for bass and panfish is this: bass and panfish eat insects and insect larvae, minnows, and aquatic invertebrates of all kinds. But bog lakes are poor places to find these in abundance. These waters hold animal life that is dominated by zooplankton, the *Daphnia, Diaptomus, Cyclops,* and *Rotifers* which Edward A. Birge studied so completely. These forms of life are seldom utilized by bass or panfish except-

ing in the earliest stages of life. But trout will eat them in large quantities. "These lakes," the Wisconsin biologists reasoned, "would be more productive and of more value to sport fishing if they were producing a desirable species of game fish which could utilize zooplankton as food. The rainbow trout, which can feed on zooplankton throughout its life and hence utilize more efficiently this predominant food, is such a game fish." Moreover, trout live and feed in open water in these lakes. Bass could continue to inhabit shorelines, trout would feed in the open areas.

One problem remained. The biologists asked: How would it be possible to clear up the tea-colored water of these bog lakes? The question was actually not difficult to answer. It was known that seepage water from lime-treated peat marshes used for agriculture is clear, while water from unlimed marshes is tea-colored. This observation suggested to Hasler and Wilhelm G. Einsele (an Austrian limnologist) that lime-treatment of bog lakes might clear up the water. In 1951, Hasler, Oscar M. Brynildson, and William T. Helm reported on the first lime treatment of two bog lakes in Chippewa County. The lakes are located on the property of Ben S. McGiveran, a Milwaukee businessman native to the county, whose ambition has been to develop methods to turn bog lakes into productive parts of the northern Wisconsin landscape. Hasler, Brynildson, and Helm wrote in their report:

> "After removal of the resident fish population by application of derris root, rainbow and brown trout were stocked . . . To alkalize the water before the ice went out in April, 1950, finely ground lime (calcium and magnesium hydroxide) was used. The chemical was scattered on the ice, but in subsequent additions it was poured over the bow or stern of a rowboat so that the turbulence from the outboard motor churned the powder into the water. . . By July, the water had cleared remarkably . . . a two-fold increase in transparency of the water, in addition to an increase in oxygen levels at cooler strata.
>
> "The resulting clearer waters make possible the capture of more energy from sunlight, therefore increasing general lake productivity. The production of fish can thus be raised by increasing the volume of the trophogenic zone by a relatively inexpensive procedure."

After these initial experiments, the research was expanded to four other test lakes located in Vilas County on the property of Guido Rahr. Facilities on Vilas County property were also made available by Notre Dame University. Of this program, the Wisconsin limnologists reported:

> "Before liming, the scrap fish in each of the lakes were removed. After liming had cleared up the water and plants had begun to grow, small trout were stocked, and in one lake both trout and bass were planted . . .
>
> "All of the lakes are now supporting respectable populations of rainbow trout. . . Alkalization of these lakes can be a valuable management tool if done properly with the guidance of experienced biologists. Costs range in the neighborhood of 60 cents per acre-foot for the initial treatment, and the subsequent yearly treatments are less. . . Scientific tests are necessary before treatment of any lake is conducted. In addition, a Wisconsin statute provides that permission must be secured from the Wisconsin Conservation Department before any chemical can be added to a lake. This makes it mandatory that the Department be consulted before liming of any lake is undertaken. If it is considered advisable after appropriate chemical and biological tests, permission may be granted providing the Department can be assured that the proper amounts of lime will be added.
>
> "It is probably hardly worth risking treatment of any lake with a surface temperature that goes over 74 degrees during the warm summer months unless cooler water with

adequate dissolved oxygen for trout is found at lower levels. This eliminates most of the small lakes in the southern portion of the State because there are no cold water layers to which trout can escape during summer heat and still have enough oxygen to live on."

Some deeper lakes of northern and southern Wisconsin, not only those of the bog type, have been found suited to trout, however, and have been taken into the trout stocking program carried on by the Wisconsin Conservation Department. The Department has financed much of the trout lake research, has cooperated in all phases of it, and is now carrying on a research and management program throughout the State. Weber Lake was the first lake converted to trout by the Department, and this lake has furnished one of the most interesting and valuable examples of the possibilities of this new type of game fish management.

Both bog lakes and some of the larger lakes in the State have been notably successful in rearing rainbow trout quickly to good sizes. University limnologists found that bog lakes well-suited to trout would permit fingerlings to grow into 16-inch trout in two years, and that a standing crop of 50 pounds per acre can be maintained. But trout seem incapable of reproduction in what is essentially an artificial environment for them, and trout populations in bog and other lakes must, for the present at least, be maintained by stocking. These lakes help answer an economic problem. For one thing, they are more economical than streams from a management standpoint. A greater percentage of the stocked trout are usually recaptured from lakes than are recaptured from streams. Moreover, trout grow faster and become heavier in lakes than in streams. While lakes may never supplant streams in the esteem of veteran trout fishermen, they may help supply a demand for an expansion of waters available for fishing in the State.

"If there is a demand for more suitable trout water, and if the percentage return of stocked rainbow trout is low in streams, then there are hundreds of lakes throughout northern Wisconsin and Upper Michigan highly suitable for rainbow trout, where the percentage return to the average fisherman can be extremely high. Many of these lakes are of little value to the sport fishery at present and could offer excellent angling for rainbow trout."

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"Pasteur once said: 'It is characteristic of science and progress that they continually open new fields to our vision'. To develop these new fields and to continue the progress of science, which is so necessary to our national health, welfare, and security, demands unremitting effort of all concerned."

—William B. Sarles

Chapter Twenty Five

THE NUISANCE ALGAE

In most lakes of northern Wisconsin, the plant nutrient content of the water is so low that increasing it is a major management problem. In some of Wisconsin's southern lakes, however, the opposite is true—abundant mineral and organic materials encourage such a heavy growth of algae, particularly the type known as blue-greens, that algae scums collect on the surface, where winds and currents drive them. They create unpleasant conditions for swimming, boating, and lakeshore residence. During the period of abundant algae growth—usually July and August—portions of these lakes are often unpleasant for human utilization for days or weeks at a time. This is not only a problem of recent times. It is, however, a problem somewhat aggravated by the disposal of city wastes into lakes and streams. It probably would eventually occur in every lake located near a metropolitan area. But it also occurs in lakes surrounded by rich soils; run-off water from fertilized fields or even good soil is extremely rich in mineral nutrients.

Among the lakes subject to heavy blooms of noxious algae are those of Madison. One lake is within the city, another is largely within it, and two more—of the same chain—are south of the Madison city limits. Lake Mendota is the headwater lake, followed in order by Monona, Waubesa, and Kegonsa. For many years, wastes from much of Madison's sewage system emptied into Lake Monona. Lake Mendota has been continuously provided with abundant mineral nutrients from surrounding farmland, and it has been fed by streams running through two nearby small towns. In recent years, wastes from Madison's treatment plant have been released into the Yahara just below Lake Monona. Plans are now under way to carry the treated effluent around Lakes Waubesa and Kegonsa. In summary: the headwater lake, Lake Mendota, has received farmland run-off and domestic waste of two small towns; Monona gets water from Lake Mendota and once received treated effluent but does so no longer, and the two shallow lakes at the end of the chain receive water flowing first through both Mendota and Monona. All the lakes are surrounded by rich farmland. It can be seen from this that the Madison lakes will always be in the high-nutrient category, and heavy algae blooms must be expected periodically.

The lakes have, however, served among the most important laboratories in the world for the study of problems brought about by nuisance growths of algae—

Magnified many times, this is one of the blue green algae species. Each tendril is made up of many individual algae cells.

problems which have been faced by many of the world's major cities, and which have persistently remained unsolved. For many years, the city of Zurich was a Swiss resort center, annually attracting many thousands of Europeans for swimming and boating. Near the turn of the century, explosive algae growth occurred in Lake Zurich. Swiss scientists attributed this growth to accumulated nitrogen and phosphorus entering the lake from domestic sources. Virtually the same story is told for many other Swiss, Scandinavian, and British lakes, including the Swiss Hallwilersee and Rotsee and the British Lake Windermere. In recent years, the same algae species that proved so unpleasant in Lake Zurich has been found growing in Seattle's Lake Washington. Noxious algae growth is a problem not confined to Madison's lakes; the experience gained from work on the lakes, however, has shown some methods by which the problem can be attacked. But its ultimate solution is not yet clearly in sight.

In 1889, William Trelease wrote of the Madison Lakes as follows:

> "Every summer a greenish-yellow scum occurs in greater or less quantity . . . during the hot weather of summer, after the water has been calm for a number of days in succession. When but little of it is present, it appears as fine granules suspended in the water, often scarcely visible to the naked eye except as they reflect the light, when they call to mind the dancing motes in a beam of sunlight. Under the influence of a gentle, but continuous breeze, these particles are collected into fleecy masses, and driven ashore, so that they accumulate along the margin of the lake, forming a slimy scum which quickly putrifies, giving off a very disagreeable odor. During this change, its color changes to a decided blue-green, which stains the pebbles, sticks, etc., over which it is smeared.
>
> "Usually the scum is seen in small quantity and only attracts attention for a day or two at a time, in midsummer, when it collects on the city-side of the lake; for a change in the direction of the breeze or a brisk wind from any quarter usually scatters it in a short time. In the summer of 1882, however, the working of the lakes was noticed early in June, and on the 17th of that month enough scum had collected . . . to prevent boating. . . The working of the lakes at Madison corresponds to what is known in Great Britain as the 'breaking' of small bodies of water. On the continent, a similar scum is spoken of as water bloom. In all these cases, the phenomenon depends on the multiplication of minute algae . . ."

Madison's domestic tranquility has been disrupted frequently by the lakes' problem and in 1918 steps were taken to control algae growth with chemicals. This was probably the first instance in which a city, attempting control of noxious blooms, applied copper sulfate on a large scale to open lake water. Five tons were applied to the waters of Lake Monona during 1918, and during the subsequent six years, additional treatments were made with limited success. Systematic treatment of the entire lake was begun in 1925 and 108,600 pounds were applied from May to September. During the next 20 years, amounts of copper sulfate ranging from 58,000 to 100,000 pounds were applied annually to Lake Monona. In 1926, a new sewage disposal plant was constructed below Lake Monona and within 10 years all of Madison's treated effluent was being released below this lake, a practice which has been carried on continuously since then, with the exception of the years after 1942, during which a small amount has been released into Monona from a military base. Copper sulfate treatment of Lakes Waubesa and Kegonsa was started about 1937, but the algae problem has continued, and at the present time the diversion of all effluent around all the lakes

is planned as part of the effort to accomplish some alleviation of the algae problem.

This large-scale copper sulfate treatment program (abandoned in 1954) has provided an unequalled opportunity to study the effect of copper upon life in lakes and how copper itself behaves when introduced into lake water in such large quantities. For one thing, it was found that copper remains in solution for a relatively short time, quickly sinking to the bottom where it remains as a deposit in the mud. This creates a need for repeated treatments to keep algae and aquatic plants under control. It works no change upon the basic cause of heavy growth. In addition, some University biologists believe accumulated quantities of copper will damage fish populations, sooner or later, either directly or by destroying food plants and animals. Whether this damage, once it occurred, would be permanent is, of course, not known. It is possible that the copper deposit in the bottom mud would merely be covered by sediments, and that it would have no effect on plant life, even in large quantities. In small amounts, indeed, it is tied up in harmless form with other lake chemicals. Whether a level might be reached when copper would cause damage is speculative—but, in any case, large amounts of copper are not natural to lake life and the danger always exists that excessive levels of copper would be permanently damaging.

To study these—and other—problems, the University set up a Lake Investigations Committee in 1947. Organized under the chairmanship of Villiers W. Meloche, and with William B. Sarles as executive coordinator, the Committee has worked with government organizations, private individuals, and civic groups concerned with the Madison lakes' problem. Committee members are all University researchers whose work, in one way or another, bears on lake ecology and pollution problems. Financial support of the research has been undertaken by a number of organizations including the University through Wisconsin Alumni Research Foundation grants, the Brittingham Foundation, the National Institutes of Health, the U.S. Public Health Service, Oscar Mayer and Company, and the Wisconsin Conservation Department.

The research falls into two main divisions: (1) Research on algae and the conditions necessary for algae growth; (2) research on the mineral content of the water of the Madison lakes; quantities and sources of chemical elements present; and on the possibility that they can be prevented from entering the lakes, or removed once they have entered.

In 1947, the Lake Mendota Association gave research funds for a study of the nutrition of blue-green algae. This stimulated research by Folke Skoog, Gerald Gerloff, and George P. Fitzgerald which, by 1949, resulted in a successful method for isolating and growing the bloom-producing species in pure laboratory culture, a feat that had been attempted but never accomplished by scientists at other research institutions.

Once they were able to grow blue-green algae in the laboratory, the botanists were able to tackle the algae problem directly. Then studies could be undertaken

of how closely the mineral nutrient content of living algae cells reflects the mineral content of the lake water. Do algae in mineral-rich waters contain more nitrogen and phosphorus than those in soft water lakes? The answer, Gerloff and Skoog found, is that they do—algae cell content of essential minerals can be used to evaluate nutrient supplies in lakes from which algae are collected.

But the amounts of nitrogen and phosphorus needed for growth are very small. Blue-green algae can get along with the barest essentials, but they like to fatten up on nitrogen and phosphorus if it is possible for them to do so. And in the Madison lakes these minerals are so abundant that there is never any danger the blue-greens will not have enough nitrogen and phosphorus. This fact, however, has led to one more question—and approach—to the algae problem. What mineral nutrient is in shortest supply in the lakes? If this question could be answered, would it not then be possible to direct efforts toward making the supply even shorter—and starving the algae out? University scientists are now working on this problem. "What single, essential element or mineral concerned with lake fertility is the key or controlling factor in algae growth?" they ask. "If we knew the answer, then emphasis could be placed on removal of this element, from sewage effluent, for example, and there would be some assurance that algae blooms would be reduced as a result."

There has been one other important application of the method by which blue-green algae can be grown in the laboratory. Once they were able to grow the algae, Skoog, Gerloff, and Fitzgerald set about devising a chemical that would control algae growth, much as 2,4-D controls growth of garden weeds. In 1953, these scientists reported that such a chemical had been developed during a screening program in which 300 substances were tested for their ability to kill blue-green algae without affecting other lake life. The chemical, named 2-3 dichloronaphthoquinone, is selective in its action—it kills only blue-green algae —and only a few parts per billion are required to destroy these algae species. It is apparently harmless to fish and other aquatic organisms. At the present time, however, it is costly, although the price per pound dropped 50 per cent within three years after the usefulness of the chemical was discovered.

A second approach to the problem of over-abundant growth of blue-green algae concerns the methods by which the mineral fertilizing elements—largely nitrogen and phosphorus—can be prevented from entering lakes from surrounding farmlands and from sewage effluent. W. L. Lea, Gerard Rohlich, and W. J. Katz reported in 1954 on methods they devised to remove phosphates from water before it is released by disposal plants. Their research has made a method possible by which from 96–99 per cent of the soluble phosphates can be removed during sewage treatment. If a good method to remove nitrogen can now be devised, many lake management problems posed by effluent disposal will have been solved. One approach may be that of growing algae in the effluent *before* it is released in the lakes. By growing algae in effluent, nearly all nitrogen and phosphorus is removed. The problem now is to find an inexpensive method to

filter algae from water and to find a use for algae once it has been extracted. Algae is an exceptionally rich source of protein. It seems probable that some use for it will be found.

Yet another attack on the algae problem is being made by Wisconsin scientists. How, they have asked, can mineral nutrients be prevented from entering lakes from surrounding farmlands? Rohlich, Arno T. Lenz, Reid A. Bryson, and Verner E. Suomi have conducted studies to pinpoint the sources of these elements in the 250 square miles of Lake Mendota's watershed. They have analysed the water of the 10 major streams entering the lake and have mapped the water currents by which nutrients are carried throughout Lake Mendota and the other Madison lakes. Clyde Bay of the Soil Conservation Service and M. L. Jackson of the University have measured the rate at which surrounding soil loses its plant nutrients to the lakes. They have also explored the possibility of managing crops and utilizing other erosion-preventing measures to reduce this loss. Studies of lake-bottom sediments have been conducted in an effort to learn the source of erosion materials. Arthur D. Hasler and John C. Neess are attempting to uncover conditions other than lake fertility which influence algae growth. Hasler and Elizabeth Jones reported in 1949 that heavy growths of large aquatic plants kept algae numbers at a minimum in small ponds. Whether this is also true in large lakes is not yet known.

It is not only abundance of algae that accounts for unpleasant conditions. In 1950, Bryson and Suomi made the first studies of wind-induced currents on lake surfaces. Then, in 1953, Bryson and Robert A. Ragotzkie found that plankton concentrates in certain areas on the surface of Lake Mendota as a result of these currents. Where currents converge, zooplankton and algae concentrate at the surface and form the so-called bloom which, if it remains for any length of time, results in unpleasant conditions. Where surface currents come together, water is forced downward. Plankton organisms rise to escape being swept to the lake depths. When winds and currents are strong, plankton organisms fail in their efforts to rise against the downward flow of water, but when winds are gentle, great numbers succeed in coming to the surface. This explains why blooms occur only during periods of light winds. The bloom is not a result of sudden and profuse multiplication of plankton organisms. It results from the concentrating effect of gentle winds and slowly moving currents.

Experiments have also been conducted with a mechanical harvester of large aquatic plants. Designed by Donald F. Livermore, the machine is capable of large-scale weed cutting operations and can remove the upper three to four feet of weed growth in shallow bay areas. Once this surface growth is removed, remaining plants begin rapid growth, seize the available plant nutrients, and afford direct competition to algae. This work is still in a preliminary stage, but the method would appear to be successful for at least partial removal of the minerals available for algae. Although it would necessarily be a large scale and costly operation, the extraction of nutrients from the lake water by harvesting

weeds would certainly be possible. Unless some economical use for the harvested weeds could be found, however, the expense very likely would be prohibitive.

In 1955, Oscar Mayer and Company, Madison, published a summary of lake studies which the company has financed. The firm recommended this program to improve the Madison lake conditions: (1) Increase flow through the Madison lakes by impounding water in a large reservoir during most of the year and releasing it during critical months; (2) remove weeds along shallow shorelines with the mechanical harvester; (3) treat with chemicals to temporarily alleviate particularly unpleasant conditions; (4) dredge some areas to remove heavy weed growth; (5) remove floating weeds by means of screens at points along the Yahara River; (6) harvest carp and other rough fish, thus extracting nitrogen and phosphorus from the lakes' life-cycle.

It seems apparent that no single method will solve the problem of noxious algae growth, but every hope exists that by utilizing all of the knowledge made available by research programs the algae problem can be controlled to a considerable extent in the Madison lakes, even those at the lower end of the chain. Experience gained in Madison will undoubtedly be of great value to other cities faced with like problems, and to cities in which, as populations increase, the problem will arise in the future.

The knowledge now at hand should serve to guide intelligent programs for preventing such total disaster as the complete extinction of a lake as a natural resource. The life of a lake is short enough. It can be hastened by indifference:

> "Nearly everyone knows that the life span of a lake is comparatively short. It is here today and gone tomorrow, geologically speaking. A flight over Wisconsin reveals clearly the boggy remains of many former Wisconsin lakes. In the youthful stage, lakes are generally unproductive; seldom do algae erupt to a point where they cause a nuisance. As the aging process progresses, the water becomes enriched and the lake gets shallower due to accumulated erosion and organic debris. This stage may be accelerated by encroachments from civilization: fertilizers from eroded lands, agricultural and domestic drainage. Once the lake has progressed toward this enriched stage, massive developments of algae scums may be anticipated . . . repulsive to the nose, abhorrent to bathers, repugnant to boaters, unsightly to visual esthetics, a hazard to health, and a problem in filtration and treatment for tastes and odors . . . ideal lake use is to maintain the lake in its *natural state* for the longest possible period. . .

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"Although he may hardly be aware of it, modern man believes deeply in an orderly and coherent universe. He thinks that nature can be puzzling, but is not capricious; and that the cry of a bird is somehow related to the stately motions of the stars."
—LEONARD ENGEL

Chapter Twenty Six

WATERS OF THE BRULE

WISCONSIN'S RURAL ZONING PROGRAM WAS THE RESULT OF PRACTICAL APPLICATION of the principles of forest ecology to land. A similar example of the direct application of research findings to management of a regional resource is to be found in the survey of the Brule River and its watershed, conducted by the University and the Wisconsin Conservation Department. The Brule River has a history that is typical for many rivers and streams of northern Wisconsin. In early days, the Brule was a travel route. The first record of its use is dated 1680, when Daniel Du Lhut, in the words of his journal, "took two canoes with a savage who was my interpreter, and with four Frenchmen . . . entered into a river which has its mouth eight leagues from the extremity of Lake Superior on the south side, where after having cut down some trees and broken through about 100 beaver dams, I went up said river, and then made a carry of half a league to reach a lake which emptied into a fine river which brought me up to the Mississippi." Leigh P. Jerrard, a resident of Superior who assisted in scientific studies of the Brule River, summarized the river's subsequent history:

> "Thereafter, it was used by explorers, voyageurs, missionaries, Indians, soldiers, and fur traders until about 1850 when roads were first opened through the wilderness. Warfare between the Chippewas and the Sioux in the Brule Valley continued until well into the 19th Century. Copper mining was active on the Brule in 1870. An English colony settled at the mouth of the river in 1880. After 1890 there was intense lumbering with river dams and sawmills. These enterprises are now gone and it is difficult to find any trace of them."

It is difficult to find a trace of the logging camps that once lined the Brule, but their influence is still apparent. In the days before the loggers, shorelines of the lower Brule were spruce and fir forest. The middle Brule flowed through pines and hardwoods, and the upper Brule was surrounded by bog and jack pine barrens. Today, farmland and second-growth aspen are to be found on the shores of the lower Brule. Hardwoods and pines have given way to aspen on the central and northern portions of the river. Aspen has encroached upon bogs that line the upper river. Only the jack pine barrens remain untouched. The result of these changes is clearly evident in the Brule's fishlife. Where once "an ordinary fisherman might catch a hundred fish [brook trout] a day with hook and line," nothing resembling this past abundance remains along the Brule's 49 miles of water. Once logging had begun, fishing on the Brule steadily declined.

Shortly after the turn of the century, rainbow trout were planted in the Brule to replace the declining numbers of brook trout. A trout hatchery was built in

1905 as a major feature of the Henry Clay Pierce estate, and the opinion was widely expressed that something would have to be done if the Brule was to remain a good trout stream. Heavy spring and summer rains caused floods along the river that were ruinous both to fish and the estates along the shore. In 1936, a stream improvement project was begun with federal funds and the Wisconsin Conservation Department began an annual stocking program. Then, in recognition of the fact that a management plan could not be developed without knowing what, specifically, should be done with the Brule, a complete ecological study was recommended in 1942 by the Wisconsin Conservation Commission.

The Commission asked the University to assist in the research. Eventually, additional funds from the Wisconsin Alumni Research Foundation's annual grant to the University were made available for the research program. Edward Schneberger of the Wisconsin Conservation Department and Arthur D. Hasler of the University were selected to head the project. The purpose of the survey was to "study the physical, biological, and chemical characteristics of the Brule River and its watershed so that an efficient and well-balanced fish management plan might be developed and placed into operation." In outlining the work, Schneberger and Hasler wrote:

> "The Brule River is in many ways an ideal stream upon which to conduct a broad detailed study. It is one of the few larger streams that has not been altered by dams. It does not receive sewage from industry or municipality. It contains a variety of ecological conditions. The upper section of the stream lies in a boggy, marshy area and then broadens out into widespreads approaching lake conditions. The middle section immediately below the widespreads is a stretch of 'fast water' containing many rapids. The lower section continues as a stretch of rather flat, quiet water and empties into Lake Superior."

World War II made it necessary to postpone some of the work on the Brule Survey, but University and Conservation Department biologists made an effort to carry on the work whenever wartime teaching schedules and civilian and military duties permitted. Norman C. Fassett and John W. Thomson, Jr., of the University began studies of the vegetation, past and present, of the Brule River Valley and its watershed. D. John O'Donnell, biologist at the Brule Ranger Station, wrote a history of fishing on the Brule in addition to conducting a census of the numbers and kinds of fish caught by anglers. O'Donnell also made a study, assisted by Warren Churchill, of fish populations, travels, spawning, food, and the chemistry of Brule waters. Richard I. Evans of the University studied river bottom sediments to learn the origin of materials that had washed into the river. State Geologist Ernest F. Bean and Thomson studied the topography and geology of the Brule basin. M. F. Schweers of the Soil Conservation Service and O. R. Zeasman of the University studied erosion problems arising along stream banks from roads and encroaching farmlands. Churchill studied the brook lamprey, and Jacob H. Fischthal of the Spooner Ranger Station studied the parasites of Brule River fish. And many other individuals took part in the work, one way or another.

The Brule is seen best by canoe . . .

Bean and Thomson made the deduction that the Brule had, for a post-glacial interval, been an outlet stream for Lake Superior, flowing to the St. Croix and, ultimately, the Mississippi River. In explaining the geological history of the Brule basin, Bean and Thomson pointed out that as the glacier retreated, the level of Lake Superior fell, and at some distant date the flow of water through the Brule basin was reversed.

Of the study conducted by Schweers and himself, Zeasman has written:

> "The upland in the watershed of the upper Brule is sand and gravelly material, providing conditions ideal for springs and seepage zones. Some peat beds exist in this section. They seem to lie as steep benches on the margin, where heavy seepage zones exist. Part of the largest marsh we saw was in a flat location that may have been a lake originally. . . The stream bed was generally sand and gravel. This material was generally so coarse that there was very little movement of it by the stream except as rolling bed load. The peat banks where we observed them were of rather fibrous material that did not appear to erode badly. In brief, conditions were for a stream of clear cool water."

He added that the soil of the lower Brule, in origin and character, is radically different from that of the upper Brule, and stream bank and channel erosion existed here before the day of lumbering and farming. It is doubtful, Zeasman said, that this section of the Brule ever provided optimum trout habitat.

The research of both Thomson and Evans showed that the bog of the upper Brule and the valley around it hold most of the present-day possibilities for maintaining the Brule as a trout stream. Without this bog, the Brule would quickly be destroyed for this purpose. Evans pointed out that the bog, if undamaged, will continue to act "as a reservoir and as a regulator of the flow of water into the stream" and that it would allow "essentially nothing in the way of the products of erosion from surrounding areas to reach the stream."

After searching through the old records of the original land survey of the Brule area, conducted in 1852–56, Fassett wrote:

> "The bog, about a mile wide and 10 miles long, which borders the upper Brule, is in nearly its original condition, except for the removal of scattered large pines and the complete cutting and burning of a few small portions. The sandy barrens, mostly southeast but also to some extent on the northwestern side of the upper Brule, is frequently burned over, with a usually sparse ground cover of small jack pines and scrub oaks, just as it was a century ago. The valley of the principal tributary, Nebagamon Creek, originally had a land cover varying from pine barrens and aspen scrub to mixed pine and hardwoods and maple forest. This was because it was so dissected by lakes and bogs that fires were local, rather than widespread as in the barrens. Much of this area is now cleared . . ."

And after his study of the present-day vegetation of the Brule basin, Thomson concluded:

> "It appears that the greatest factor in the maintenance of the river as a suitable habitat for trout is the coniferous forest swamp which occupies the upper valley. The numerous springs in this region, and the large swampy area with an abundance of absorbent humus make this stream unusual among most streams in this area of northern Wisconsin and are good combinations for maintaining a very even flow of water. . . The lower section, largely flowing through a clay soil belt, has very few aquatic plants, probably because of the heavy burden of silt in the water."

Thomson recommended a nine-point program to help improve the present condition of the Brule: (1) Cease the cutting of timber throughout the entire headwater area; (2) encourage growth of alder swamp vegetation; (3) leave fallen

timber, for it is "an essential part of the forest floor" and prevents erosion by forming a layer of woody peat and encouraging plant growth on the forest floor; (4) no roads or other clearing should be permitted in the headwater swamp area; (5) wild rice and yellow water lily should be planted along the shores of Big and Lucius Lakes; (6) halt pulpwood lumbering on the shores of the lower valley to reduce silting of the river and slumping of the banks; (7) institute erosion control along the Nebagamon and the lower Brule; (8) plant white cedar and willow to anchor slipping river banks; (9) control erosion from highway ditches and banks draining into the river.

The consequence of the Brule Survey was that, as early as 1944, the upper Brule watershed and bog were being protected from further damage through a program of State acquisition. In addition, the first of a series of scientific papers providing a record of the survey was published in the *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters.* The last paper in the series was published in 1954. These scientific reports summarize one of the most complete studies ever made of a North American stream and the life in it, and they provide the basis for a management program that should continue to improve the Brule as trout water for years to come. The findings obtained during the course of the Brule Survey have been applied to the management programs for many other northern Wisconsin trout streams. Problems exist which must yet be solved, but much of the fundamental research has already been conducted. The Brule's history clearly demonstrates the damage that can be done by an absence of effective watershed management. Restoration of the Brule to a condition somewhat resembling its original state is a tribute to the effectiveness of research in furnishing the facts by which renewable resources can be preserved and their full potentialities realized.

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"Half a century hence we shall be farming our good lands better and more intensively and, if the population situation does not quite blind us, the marginal lands will be in course of repair to the state where they can yield that which nature allows them to produce."

—F. Fraser Darling

Epilogue

THE ROSTER OF SUPPORT

In the three decades since it was founded, the Wisconsin Alumni Research Foundation has provided the University of Wisconsin with research funds exceeding $15,000,000 in amount, and the Foundation's annual grant to the University for research programs in the natural sciences now surpasses $1,000,000 each year. The major portion of this annual grant is used directly for research; lesser amounts are used to amortize the cost of various buildings, support professorships in the sciences, sponsor symposia, purchase items of equipment, and finance an extensive fellowship program which brings the nation's outstanding young scientists to the Wisconsin campus for graduate study.

Without the annual Foundation grant, the University undoubtedly could never have reached the eminent scientific position it now holds among the universities of the world. The funds support studies in the natural sciences, physics and chemistry, mathematics, geology, and all of the others, as well as in the biological sciences. It is research on certain aspects of the biological sciences which has been reported in this book.

While the Foundation's grant has served as the financial core upon which this enormous research program has been built, there have been a multitude of additional sources for support. It is impossible to mention all the many persons, organizations, and groups that have provided funds and other means of support to accompany and augment the Foundation's grants for research on the State's renewable resources. However, the major donors should be acknowledged. Many of them have given directly to the University, others to the Foundation, and many of them have financed fellowships and scholarships for students. It is hoped no one has been omitted in the following lists; it is almost impossible that many have not been. It should be noted that two federal acts, the Pittman–Robertson Act and the Dingell–Johnson Act, are now providing research funds for state agencies through a tax on sporting equipment. This legislation has provided greater benefits to the cause of good resource management than perhaps any other recent government effort.

Those groups and individuals that have provided major support to the natural resources research program of the University of Wisconsin, in addition to that provided by the Wisconsin Alumni Research Foundation, are as follows:

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U.S. Fish and Wildlife Service
Sporting Arms and Ammunition Manufacturers' Institute
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